US009265051B2

(12) **United States Patent**
Yu et al.

(10) **Patent No.: US 9,265,051 B2**
(45) **Date of Patent: Feb. 16, 2016**

(54) **TIME SHIFTING OF CO-CHANNEL DATA TRANSMISSIONS TO REDUCE CO-CHANNEL INTERFERENCE**

(71) Applicant: **QUALCOMM Incorporated**, San Diego, CA (US)

(72) Inventors: **Zhi-Zhong Yu**, Farnbrough (GB); **Mungal Singh Dhanda**, Slough (GB)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 282 days.

(21) Appl. No.: **13/909,254**

(22) Filed: **Jun. 4, 2013**

(65) **Prior Publication Data**

US 2013/0281101 A1 Oct. 24, 2013

Related U.S. Application Data

(63) Continuation of application No. 13/263,983, filed as application No. PCT/US2010/034311 on May 11, 2010.

(60) Provisional application No. 61/177,207, filed on May 11, 2009.

(51) **Int. Cl.**

H04W 72/00	(2009.01)
H04W 72/08	(2009.01)
H04W 52/32	(2009.01)
H04W 52/16	(2009.01)
H04W 72/04	(2009.01)
H04L 25/03	(2006.01)

(52) **U.S. Cl.**
CPC ***H04W 72/082*** (2013.01); ***H04W 52/325*** (2013.01); *H04L 25/03012* (2013.01); *H04L 2025/03426* (2013.01); *H04W 52/16* (2013.01); *H04W 72/0446* (2013.01)

(58) **Field of Classification Search**
CPC H04W 52/325
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,386,589 A 1/1995 Kanai
5,930,248 A 7/1999 Langlet et al.

(Continued)

FOREIGN PATENT DOCUMENTS

AU 687225 B2 2/1998
CN 1207859 A 2/1999

(Continued)

OTHER PUBLICATIONS

European Search Report—EP13020079—Search Authority—Munich—Sep. 6, 2013.

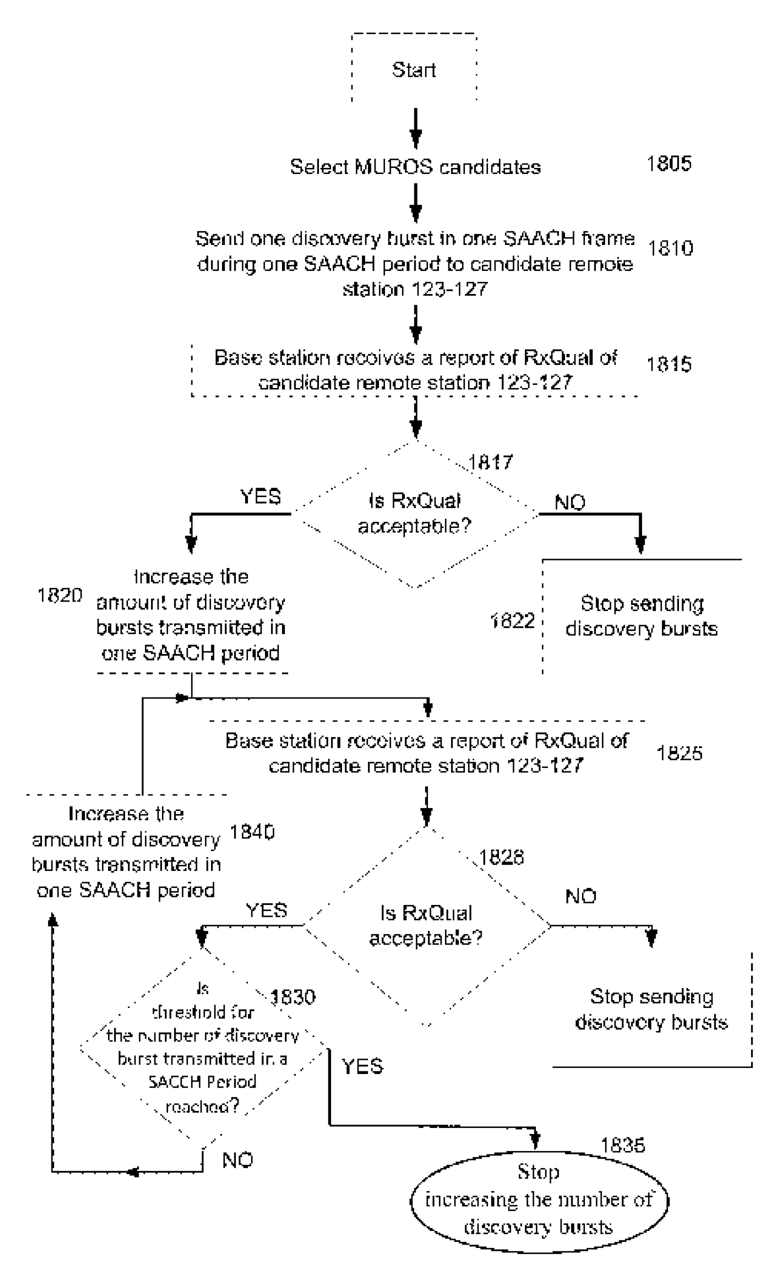
(Continued)

Primary Examiner — Huy D Vu
Assistant Examiner — Kevin Cunningham
(74) *Attorney, Agent, or Firm* — Larry Moskowitz

(57) **ABSTRACT**

A cellular communications system in which transmission of control signals for plural different remote stations is so displaced in time that the transmission of control signals for one remote station does not interfere with the transmission of control signals for another remote station, the displacement being sufficient to prevent contemporaneous reception of control signals by the remote station intended for the other remote station. Other aspects, embodiments, and features are also claimed and described.

39 Claims, 24 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

5,930,706	A	7/1999	Raith	
5,937,019	A	8/1999	Padovani	
6,456,606	B1	9/2002	Terasawa	
6,785,250	B2	8/2004	Vayanos et al.	
6,996,083	B1	2/2006	Balachandran et al.	
7,003,310	B1	2/2006	Youssefmir et al.	
7,649,869	B2	1/2010	Mittal et al.	
7,787,897	B2	8/2010	Banh et al.	
7,889,689	B2	2/2011	Sebire	
8,374,156	B2	2/2013	Yu et al.	
8,452,316	B2	5/2013	Sutivong et al.	
8,817,651	B2	8/2014	Yu et al.	
2002/0122396	A1	9/2002	Terasawa	
2003/0174675	A1	9/2003	Willenegger et al.	
2006/0018336	A1	1/2006	Sutivong et al.	
2006/0203943	A1	9/2006	Scheim et al.	
2009/0022178	A1	1/2009	Ji et al.	
2009/0201880	A1 *	8/2009	Aghili et al.	370/331
2009/0279625	A1 *	11/2009	Rudolf et al.	375/260
2010/0027450	A1	2/2010	Montojo et al.	
2010/0067440	A1	3/2010	Dick et al.	
2010/0142461	A1	6/2010	Miki et al.	
2010/0279701	A1	11/2010	Chen	
2011/0014925	A1 *	1/2011	Antic et al.	455/452.2
2011/0105184	A1	5/2011	Piirainen et al.	
2011/0267968	A1	11/2011	Yu et al.	
2012/0113878	A1	5/2012	Yu et al.	
2013/0201860	A1	8/2013	YU; Zhi-Zhong et al.	

FOREIGN PATENT DOCUMENTS

CN	1255258	A	5/2000
CN	1780180	A	5/2006
FR	2724509		3/1996
JP	H05244056	A	9/1993
JP	10313483	A	11/1998
JP	2002232396	A	8/2002
JP	2002528974	A	9/2002
JP	2004032202	A	1/2004
JP	2004535735	A	11/2004
JP	2005534226	A	11/2005
JP	2007529915	A	10/2007
JP	2007535872	A	12/2007
JP	2008507903	A	3/2008
JP	2008236433	A	10/2008
JP	2010534037	A	10/2010
JP	2012500515	A	1/2012
KR	19990024692		4/1999
KR	20000029825	A	5/2000
KR	20060058045	A	5/2006
KR	20070055642	A	5/2007
KR	20070082201	A	8/2007
TW	200824310	A	6/2008
WO	9720446	A2	6/1997
WO	0024206	A2	4/2000
WO	WO-2004010572	A1	1/2004
WO	2005062798	A2	7/2005
WO	WO-2005112487	A2	11/2005
WO	WO-2006007318	A1	1/2006
WO	2006019710	A1	2/2006
WO	2007022127	A2	2/2007
WO	2007048427	A1	5/2007
WO	2008045501	A2	4/2008
WO	WO-2008057843	A2	5/2008
WO	2009012272	A2	1/2009
WO	WO 2009036389	A2 *	3/2009
WO	2010021637	A1	2/2010
WO	WO-2010019556	A1	2/2010

OTHER PUBLICATIONS

3GPP TS 45.002 V4.8.0 (Jun. 2003) "Technical Specfication 3rd Generation Partnership Project; Technical Specification Group GSM/EDGE Radio Access Network; Multiplexing and multiple access on the radio path (Release 4)".

China Mobile et al: "Power assignment for MUROS" 3GPP Draft; GP-080773 Power_Assignment For_MUROS, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-Antipolis Cedex; France, No. Malaga; May 12, 2008, XP050020060.

Ericsson: "Single antenna interference cancellation a capacity estimation in unsynchronised networks"3GPP Draft; GP-031202, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-antipolis Cedex; France, vol. tsg_geran\TSG_GERAN\GERAN_15_Fort_Lauderdale\Docs, No. Fort Lauderdale, USA; Jun. 23, 2003, Jun. 19, 2003, XP050008475.

European Search Report—EP13001537—Search Authority—Munich—Apr. 25, 2013.

International Search Report and Written Opinion—PCT/US2010/034311—International Search Authority, European Patent Office, Sep. 29, 2010.

Marvell: "Higher Order Modulations for MUROS a Concept Description" 3GPP Draft; GP-080652—Higher Order Modulations for MUROS, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre ; 650, Route Des Lucioles ; F-06921 Sophia-Antipolis Cedex France, vol. TSG GERAN, No. Malaga; May 12, 2008, May 6, 2008, XP050019950.

Mouly M., et al., "Radio Resource Management" Jan. 1, 1993, GSM System for Mobile Communications, Lassay-Les-Chateaux, Europe Media, FR, pp. 308-430, XP000860006, p. 342, paragraph 6.1.5—p. 349, paragraph 6.1.5.2.

Taiwan Search Report—TW099115035—TIPO—Aug. 11, 2013.

European Search Report—EP13160712—Search Authority—Munich—Oct. 21, 2013.

3GPP TR 45.914, "Digital cellular telecommunications system (Phase 2+); Circuit switched voice evolution for GSM/EDGE Radio Access Network (GERAN)", ETSI TR 145 914 V8.0.0, Release 8, Apr. 2009, 211 Pages.

3GPP TSG GERAN #40, "Additional ink level performance results for Co TCH", Tdoc GP-081496, Nov. 21, 2008, URL, http://www.3gpp.org/ftp/tsg_geran/TSG_GERAN/GERAN_40_Miami/Docs/GP-081496.zip.

* cited by examiner

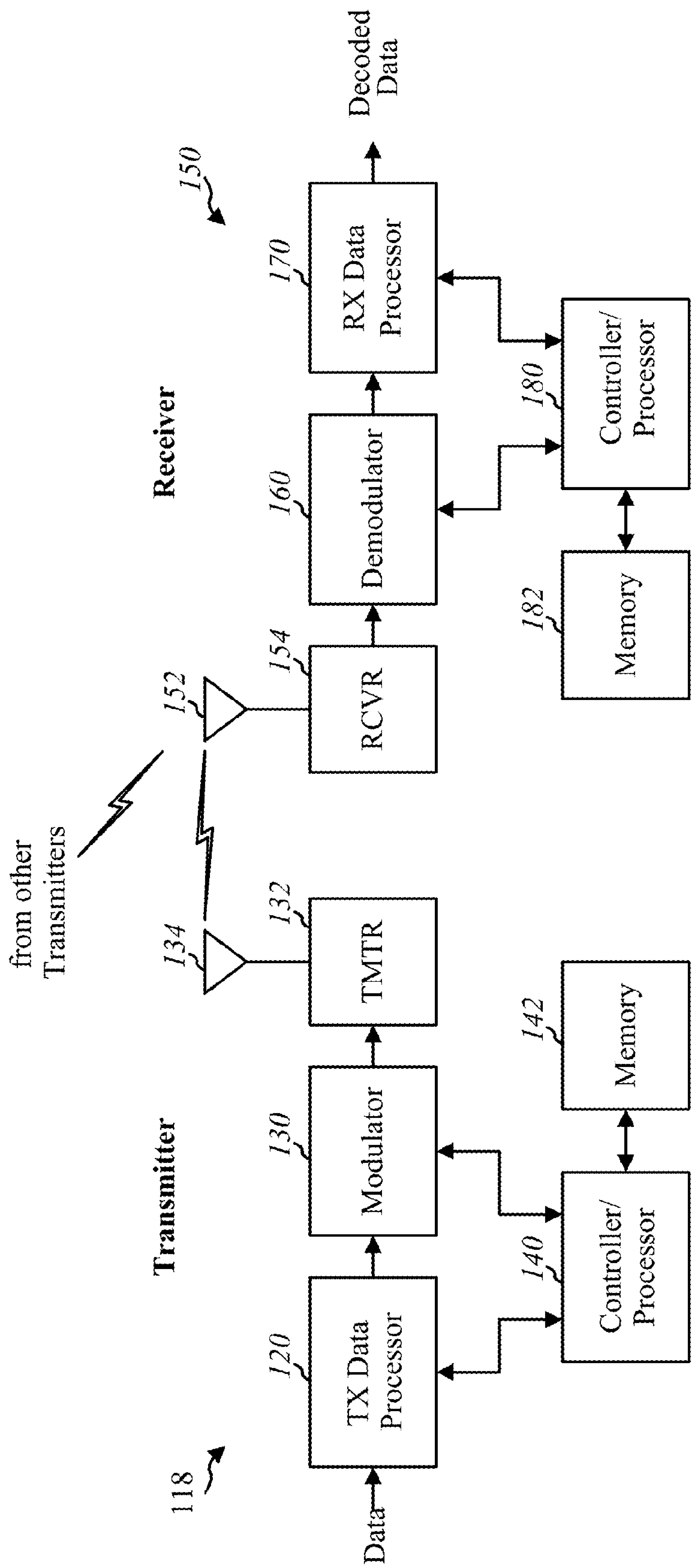

Decoded Data
150
Receiver
170
RX Data Processor
160
Demodulator
154
RCVR
152
180
Controller/ Processor
182
Memory
from other Transmitters
134
132
TMTR
Transmitter
130
Modulator
142
Memory
140
Controller/ Processor
120
TX Data Processor
118
Data

FIG. 1

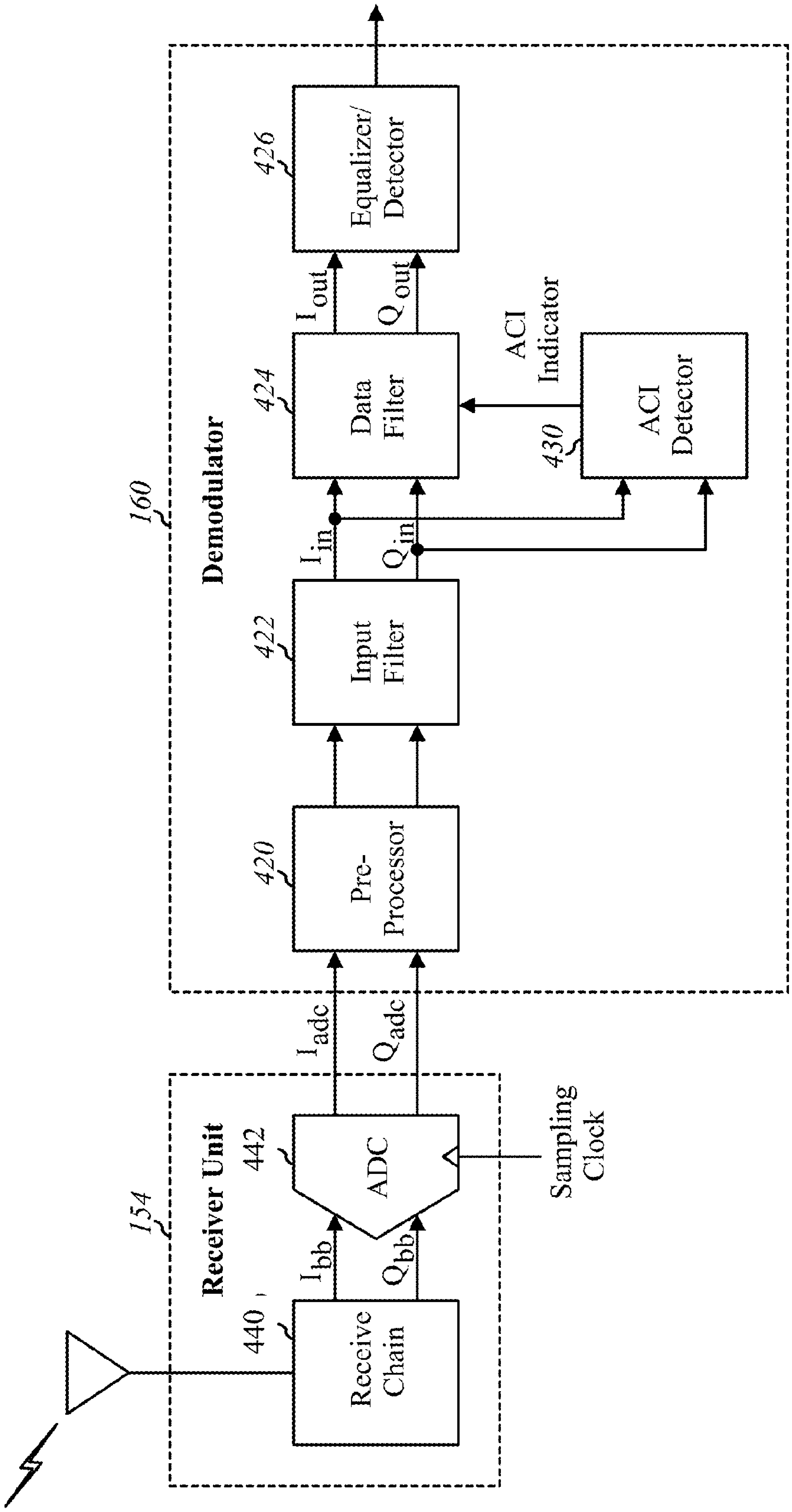
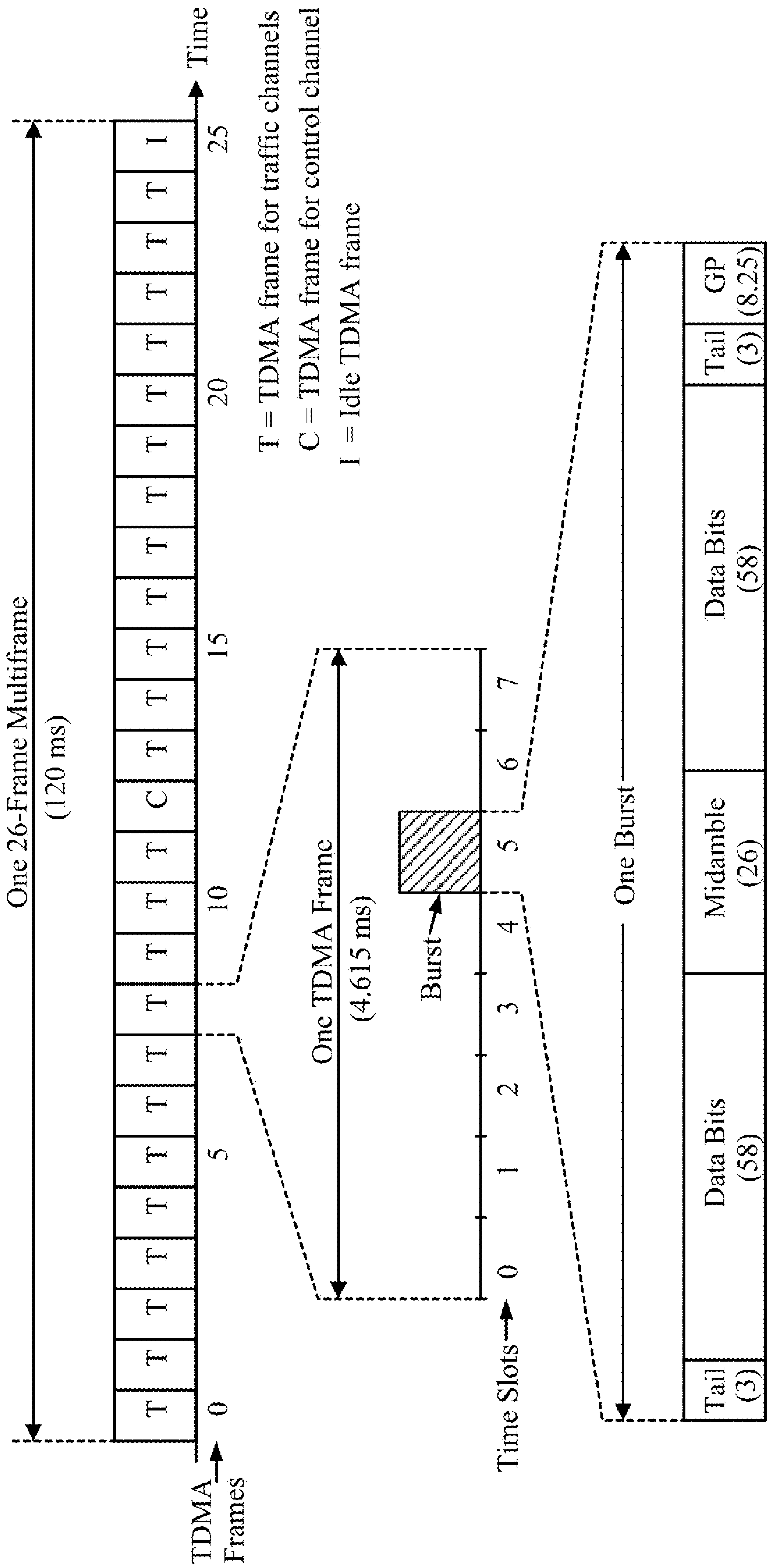

160
Demodulator
420
Pre-Processor
422
Input Filter
424
Data Filter
426
Equalizer/ Detector
430
ACI Detector
ACI Indicator
I_{in}
Q_{in}
I_{out}
Q_{out}
I_{adc}
Q_{adc}
154
Receiver Unit
440
Receive Chain
442
ADC
I_{bb}
Q_{bb}
Sampling Clock

FIG. 2



One 26-Frame Multiframe
(120 ms)
Time
TDMA Frames
T T T T T T T T T T T T C T T T T T T T T T T T T I
0
5
10
15
20
25
T = TDMA frame for traffic channels
C = TDMA frame for control channel
I = Idle TDMA frame
One TDMA Frame
(4.615 ms)
Burst
Time Slots
0 1 2 3 4 5 6 7
One Burst
Tail (3)
Data Bits (58)
Midamble (26)
Data Bits (58)
Tail (3)
GP (8.25)

FIG. 3

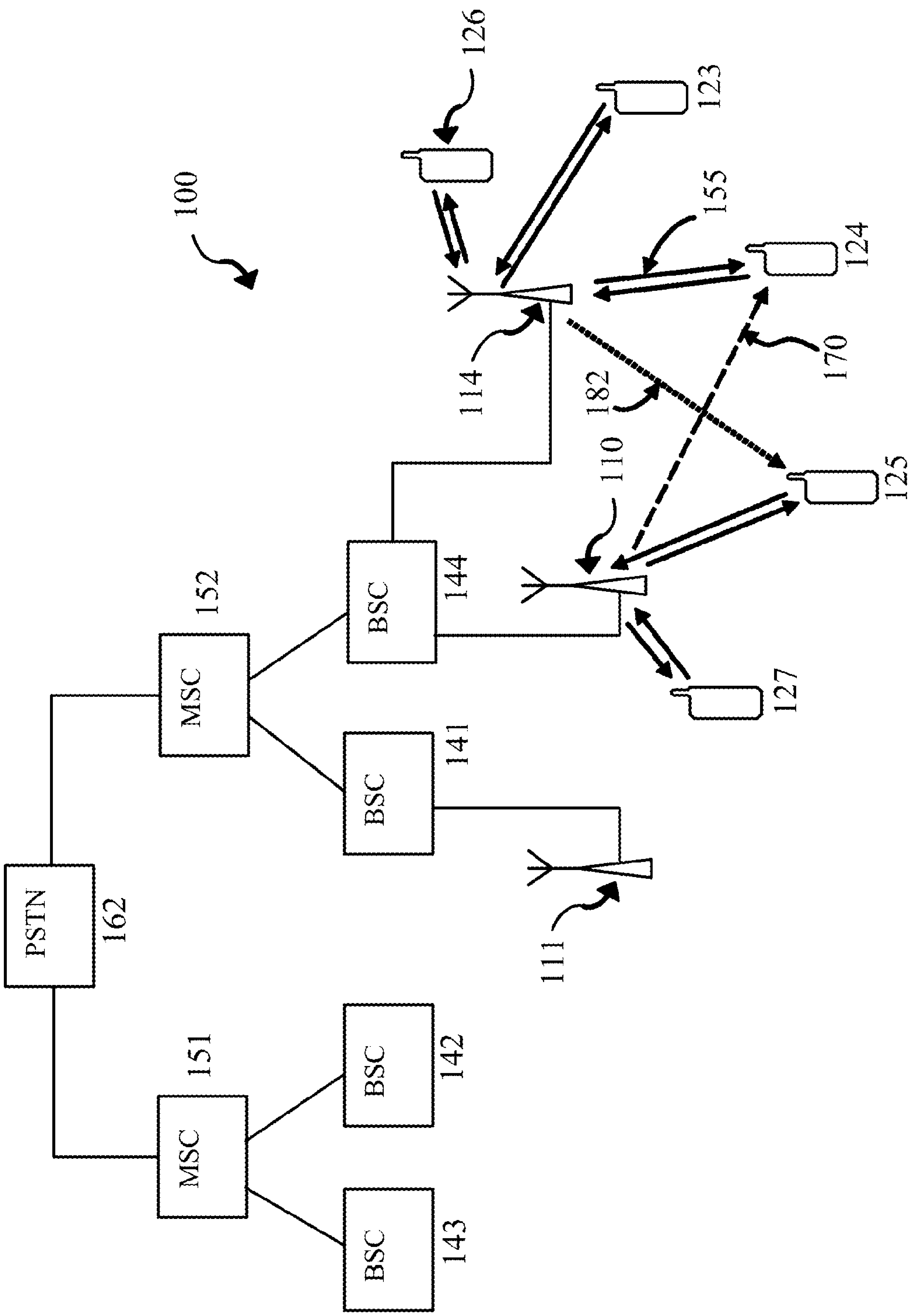

100
126
123
155
124
114
182
170
110
125
152
MSC
BSC
144
127
141
BSC
PSTN
162
111
151
MSC
BSC
142
BSC
143

FIG. 4

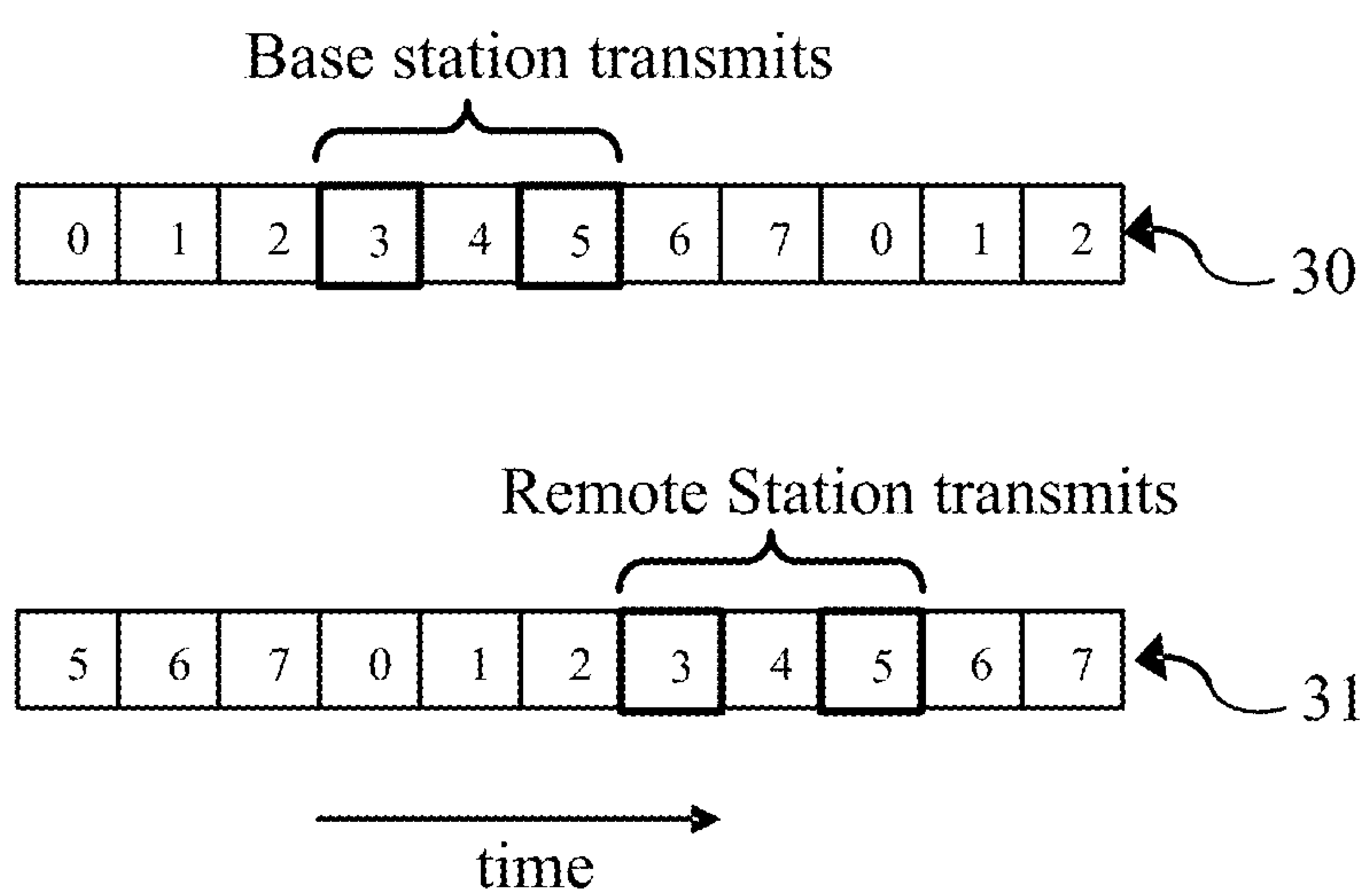

Base station transmits
0
1
2
3
4
5
6
7
0
1
2
30
Remote Station transmits
5
6
7
0
1
2
3
4
5
6
7
31
time

FIG. 5

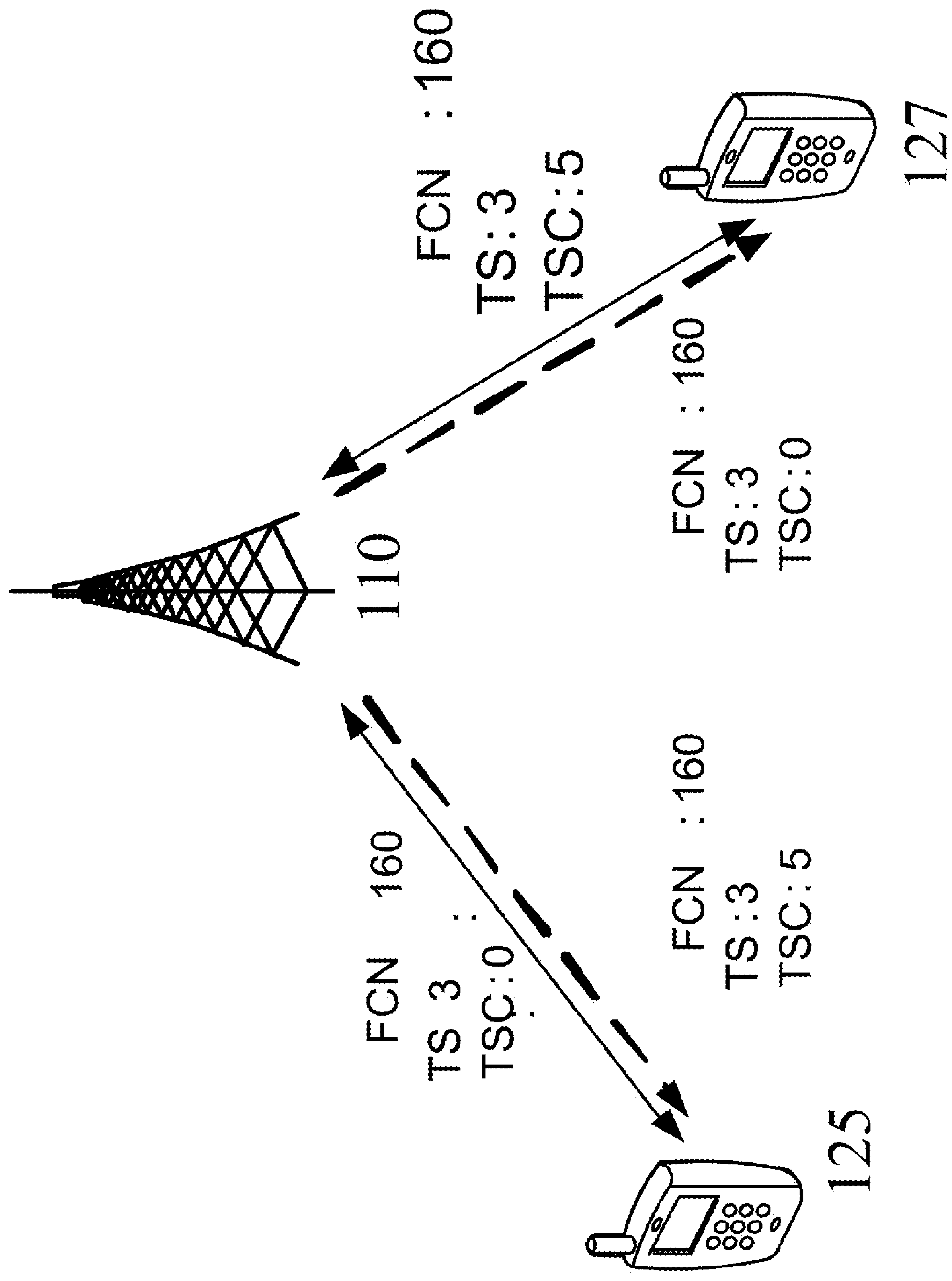

FCN : 160
TS: 3
TSC: 5
127
110
FCN : 160
TS : 3
TSC: 0
FCN 160
TS 3
TSC:0
FCN : 160
TS : 3
TSC: 5
125

FIG. 6

1001

Channel Freq.	Remote Station
1	125
4	127
32	126
…	…
64	151
71	96
…	…

1002

Time slot	Remote Station
0	96
…	…
3	123
3	124
3	229
…	
5	126
5	252

1003

TSC	Remote Station
0	
1	125
2	
3	
4	127
5	

Memory

1005

Base Station	Freq allocation set	Channel freq.	DL Time slot	TSC	Remote Station
110	f1	32	3	1	125
110	f1	32	3	4	127
….	….	…	…	…	….
114	f1	32	3	0	
114	f1	32	3	1	
114	f1	32	3	2	123
114	f1	32	3	3	124
114	f1	32	3	7	
…	….	….	….	….	….
114	f1	32	5	3	126
…	….	….	….	….	….
118	f1	32	3	A	733
118	f1	32	3	C	255

FIG. 7

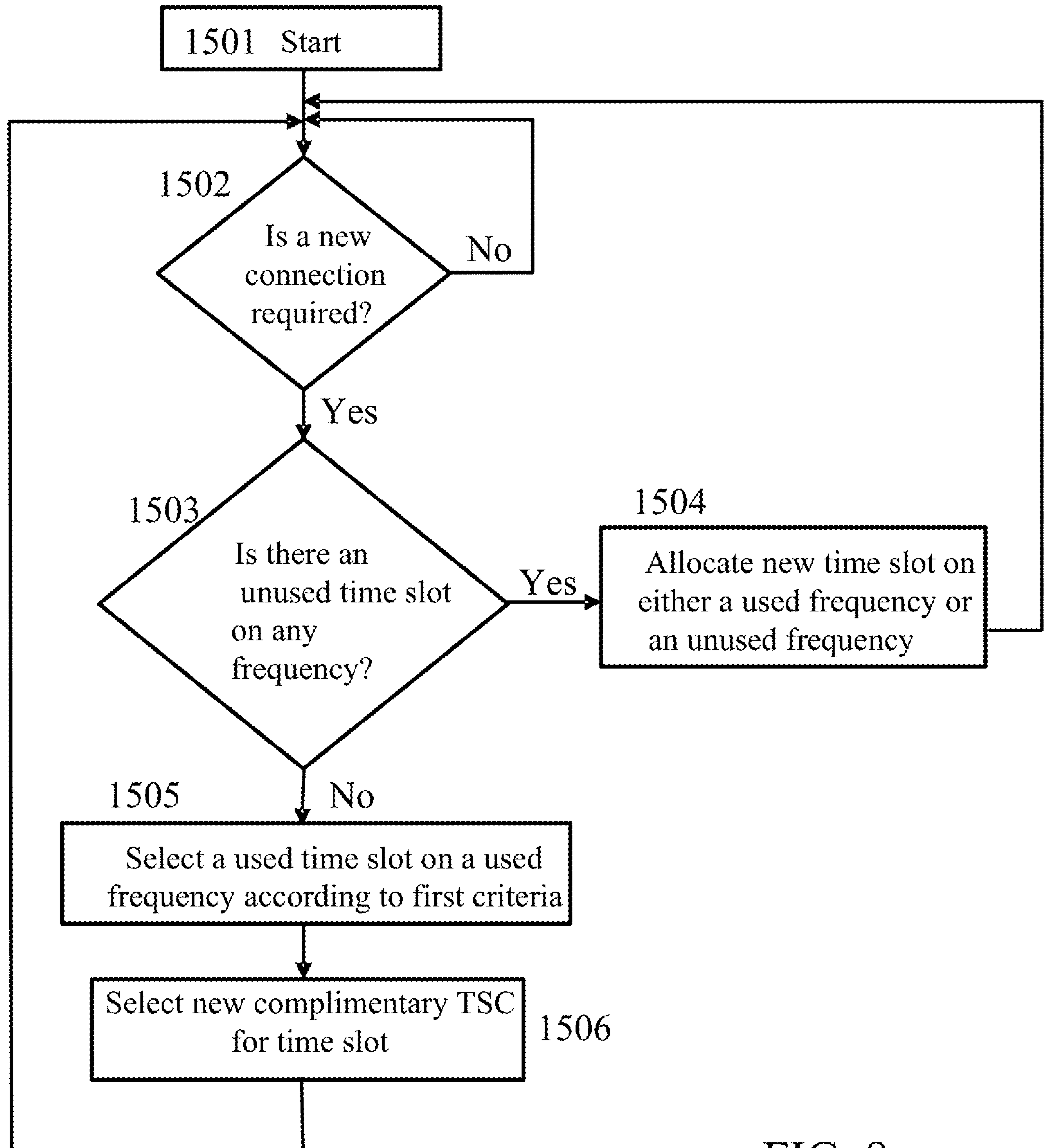

1501 Start
1502
Is a new connection required?
No
Yes
1503
Is there an unused time slot on any frequency?
Yes
1504
Allocate new time slot on either a used frequency or an unused frequency
1505
No
Select a used time slot on a used frequency according to first criteria
Select new complimentary TSC for time slot
1506

FIG. 8

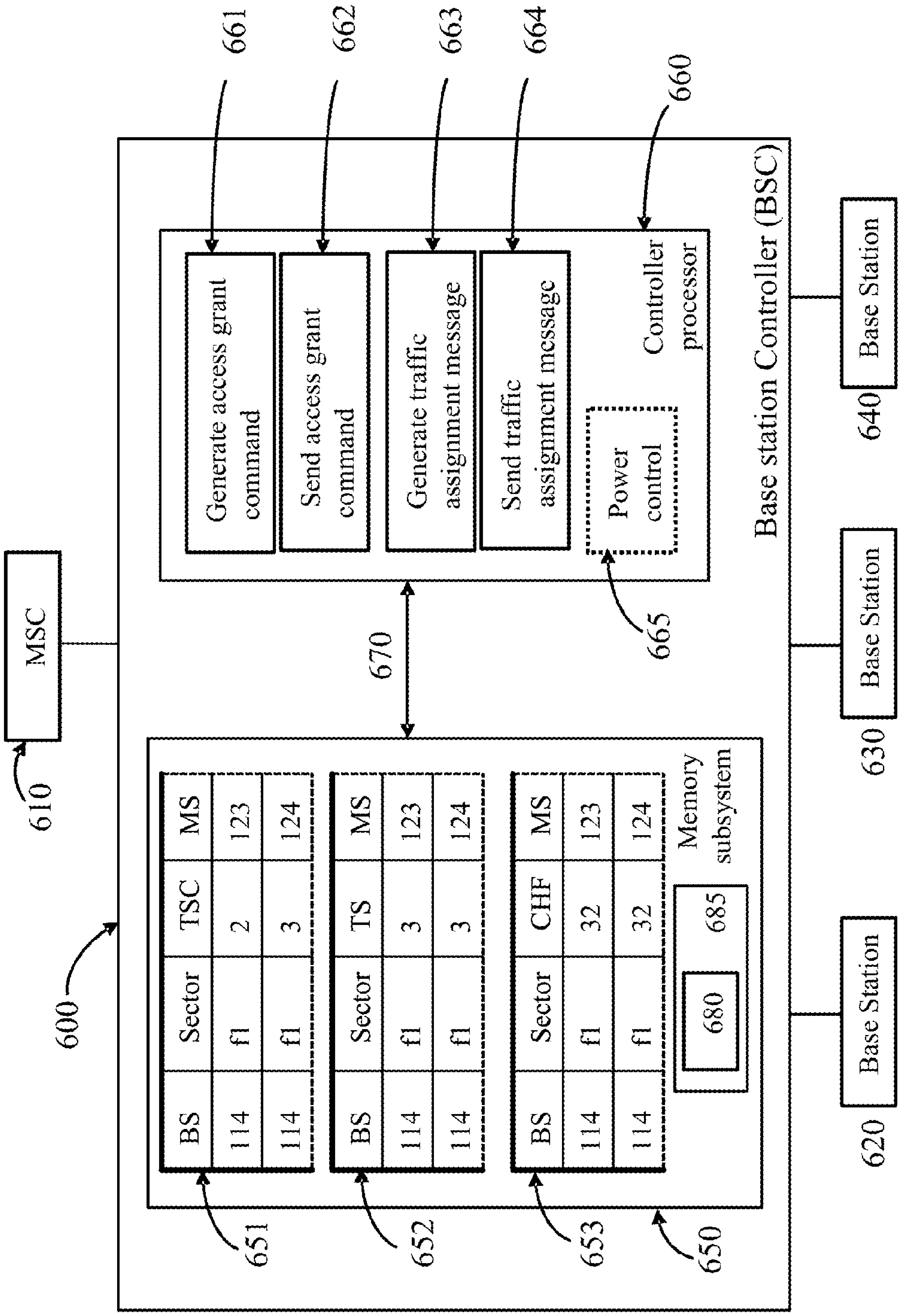

661
662
663
664
660
Generate access grant command
Send access grant command
Generate traffic assignment message
Send traffic assignment message
Power control
Controller processor
Base station Controller (BSC)
Base Station
640
Base Station
630
Base Station
620
MSC
610
600
665
670
BS
Sector
TSC
MS
114
f1
2
123
114
f1
3
124
BS
Sector
TS
MS
114
f1
3
123
114
f1
3
124
BS
Sector
CHF
MS
114
f1
32
123
114
f1
32
124
680
685
Memory subsystem
651
652
653
650

FIG. 9

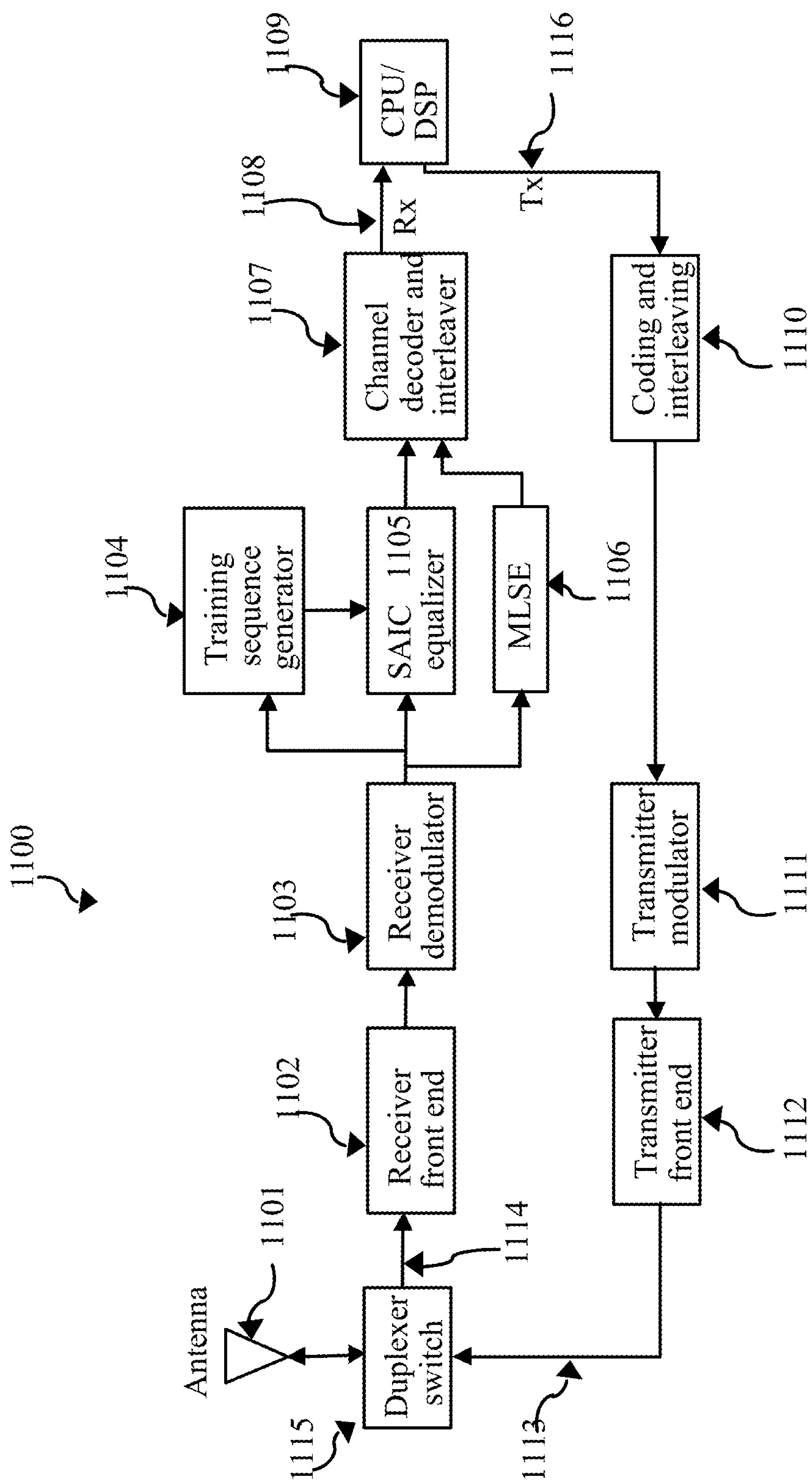

1100
Antenna
1101
1115
Duplexer switch
1114
1113
Receiver front end
1102
Receiver demodulator
1103
Training sequence generator
1104
SAIC 1105 equalizer
MLSE
1106
Channel decoder and interleaver
1107
Rx
1108
CPU/ DSP
1109
Tx
1116
Coding and interleaving
1110
Transmitter modulator
1111
Transmitter front end
1112

FIG. 10

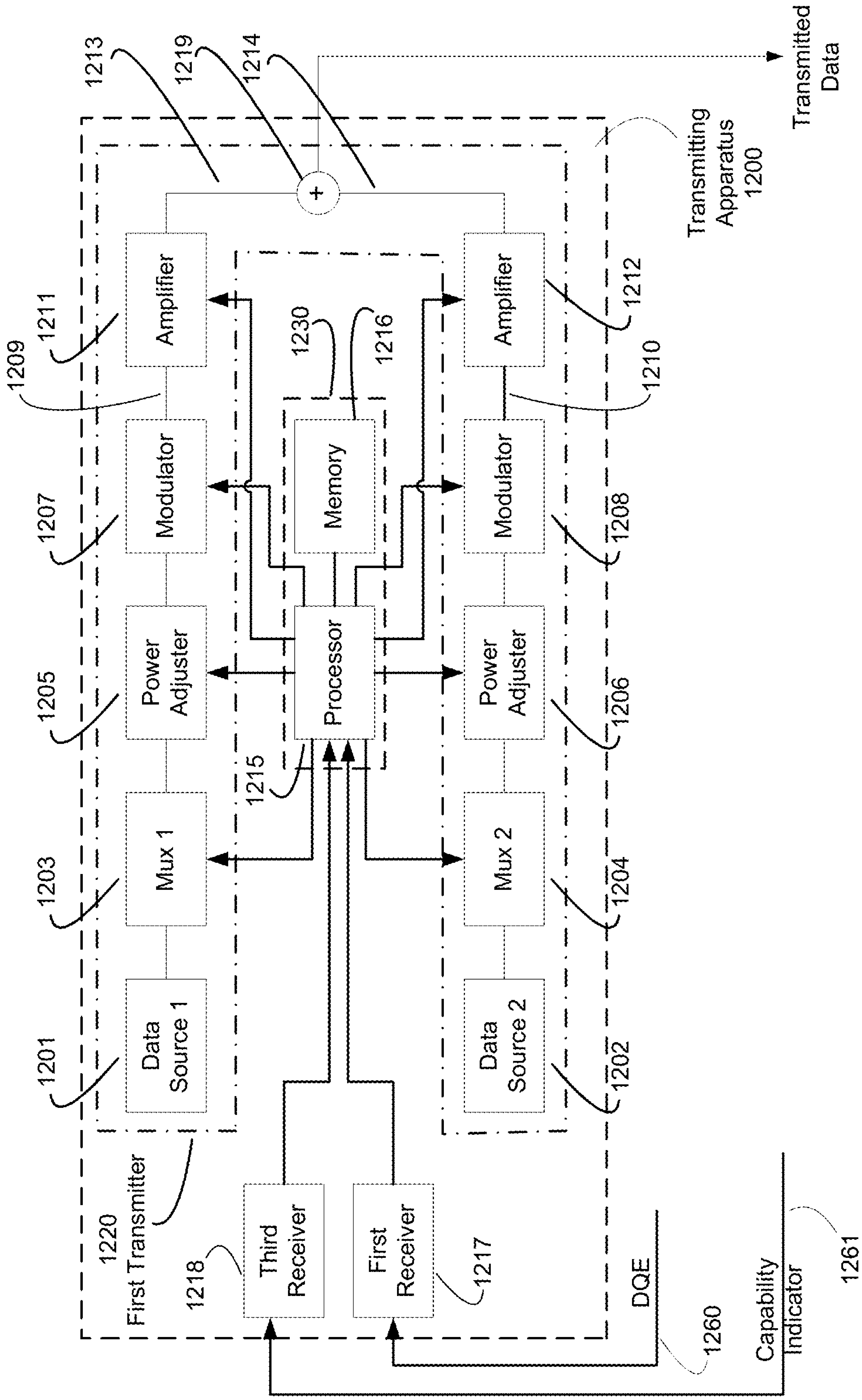

Data Source 1
Mux 1
Power Adjuster
Modulator
Amplifier
Data Source 2
Mux 2
Power Adjuster
Modulator
Amplifier
Processor
Memory
Third Receiver
First Receiver
First Transmitter
1220
Transmitting Apparatus 1200
Transmitted Data
DQE
Capability Indicator
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1230
1260
1261

Figure 11a

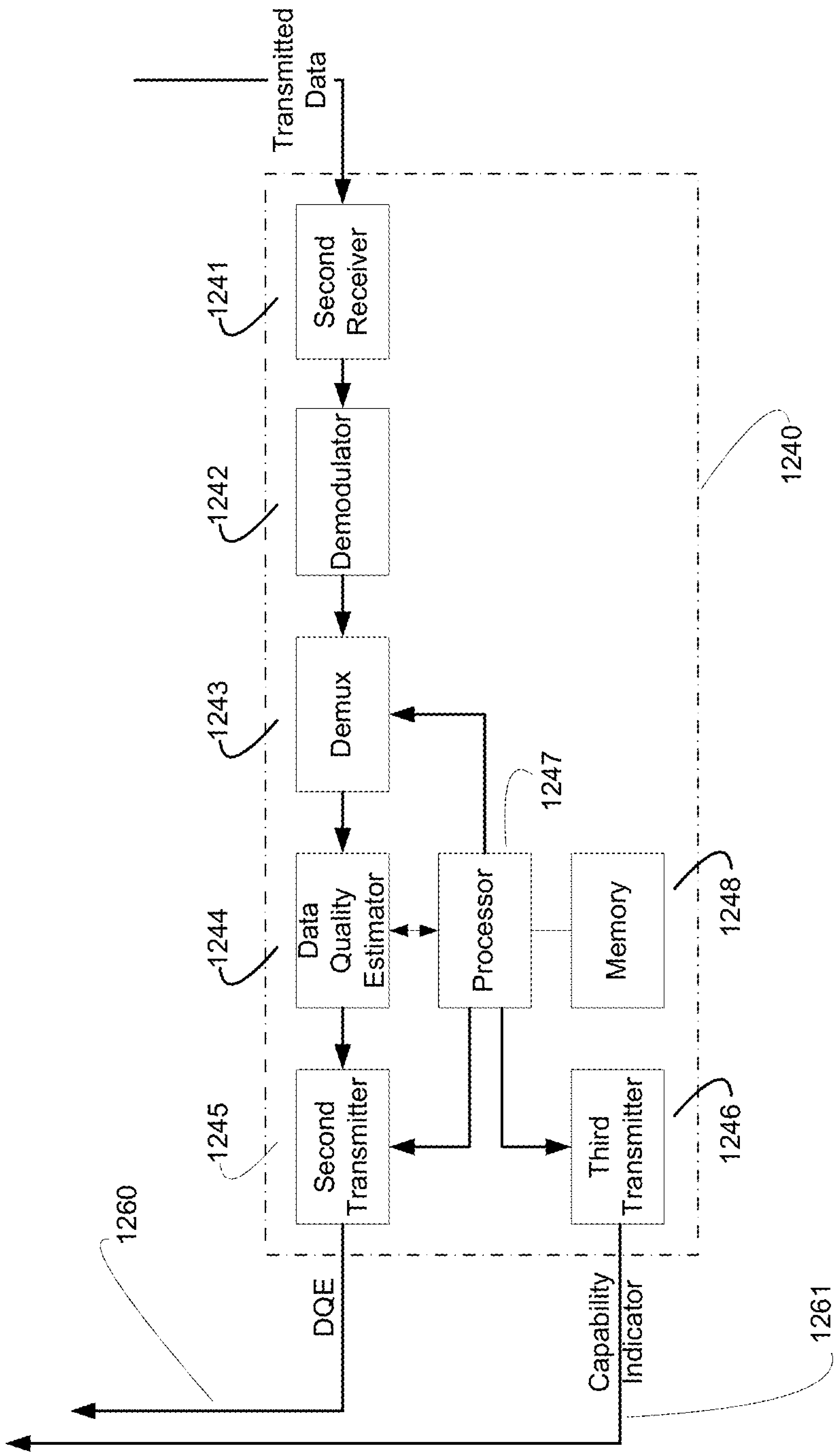

Transmitted Data
1241
Second Receiver
1242
Demodulator
1240
1243
Demux
1247
1244
Data Quality Estimator
Processor
Memory
1248
1245
Second Transmitter
Third Transmitter
1246
1260
DQE
Capability Indicator
1261

Figure 11b

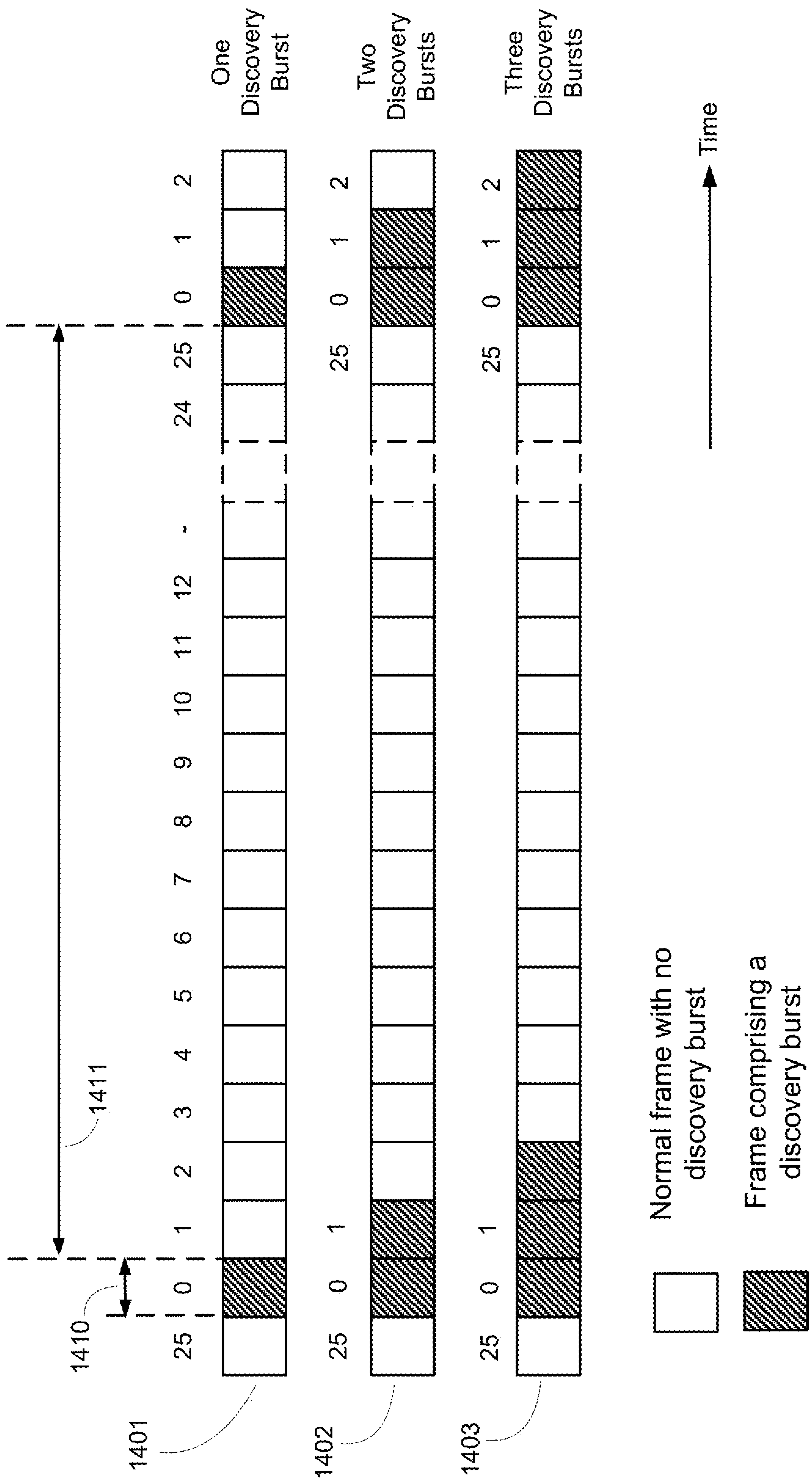

One Discovery Burst
Two Discovery Bursts
Three Discovery Bursts
Time
1401
1402
1403
1410
1411
Normal frame with no discovery burst
Frame comprising a discovery burst

Figure 12A

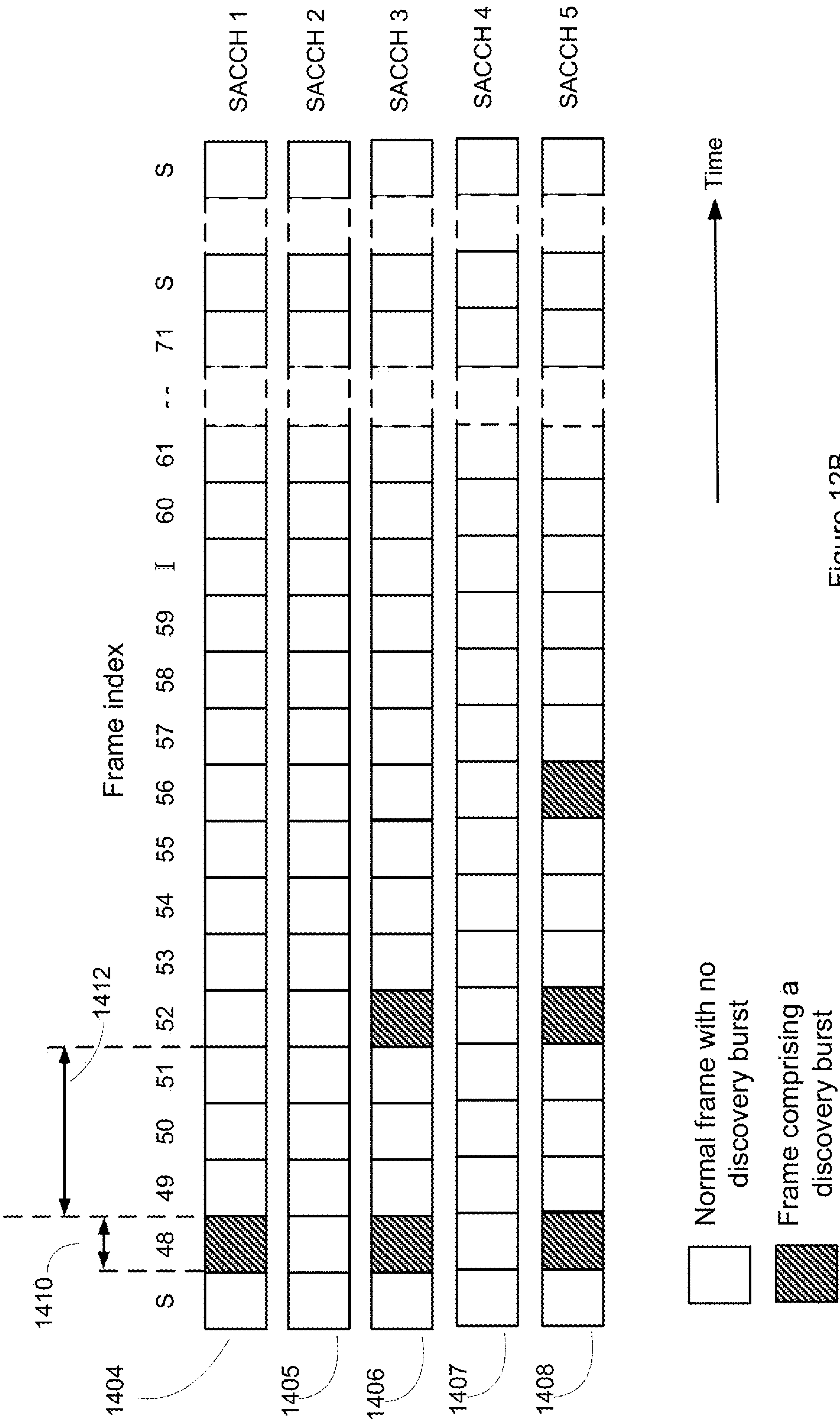

Frame index
S
48
49
50
51
52
53
54
55
56
57
58
59
I
60
61
--
71
S
S
SACCH 1
SACCH 2
SACCH 3
SACCH 4
SACCH 5
1404
1405
1406
1407
1408
1410
1412
Time
Normal frame with no discovery burst
Frame comprising a discovery burst

Figure 12B

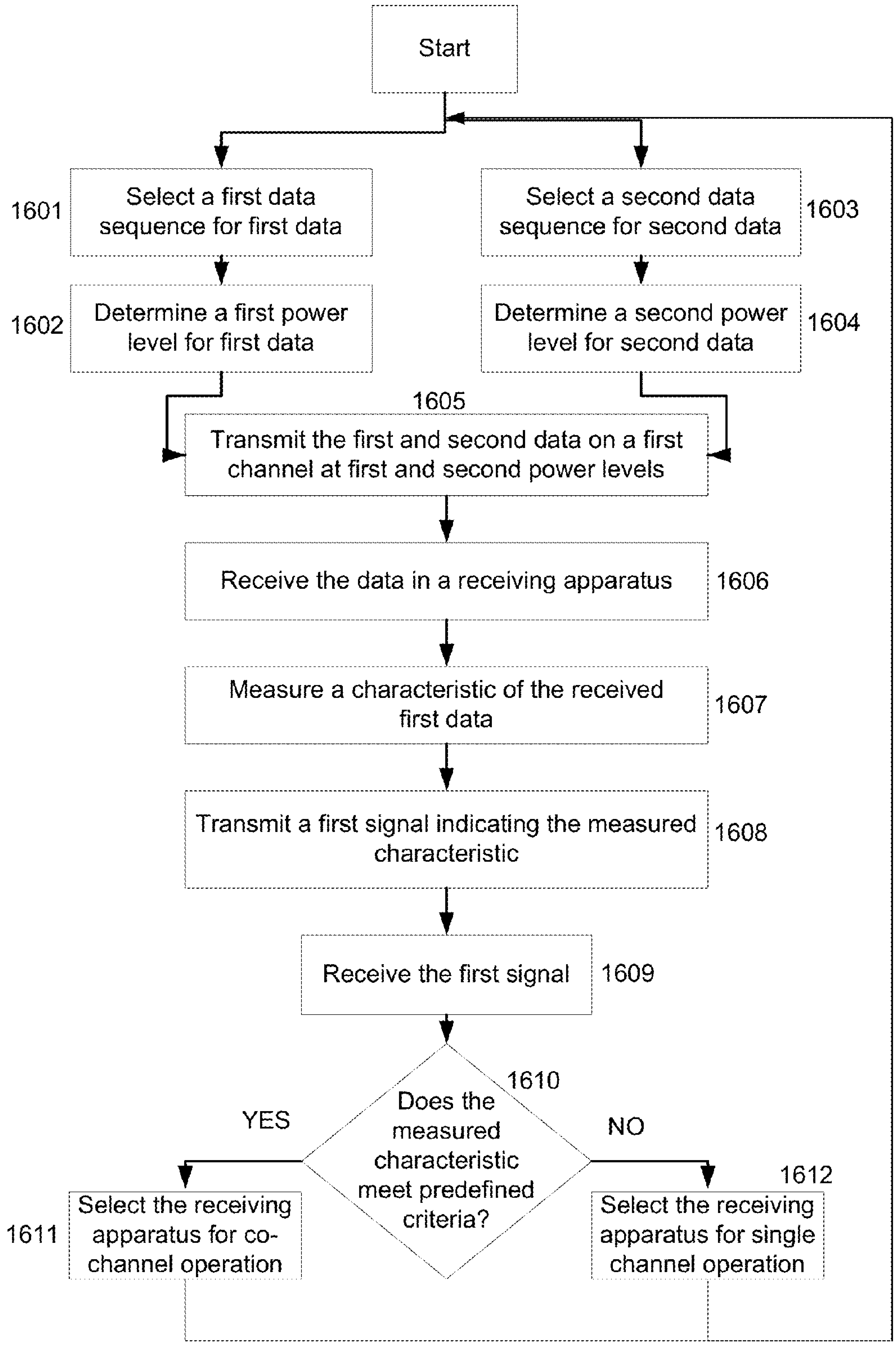

Start
Select a first data sequence for first data
1601
Determine a first power level for first data
1602
Select a second data sequence for second data
1603
Determine a second power level for second data
1604
1605
Transmit the first and second data on a first channel at first and second power levels
Receive the data in a receiving apparatus
1606
Measure a characteristic of the received first data
1607
Transmit a first signal indicating the measured characteristic
1608
Receive the first signal
1609
Does the measured characteristic meet predefined criteria?
1610
YES
NO
Select the receiving apparatus for co-channel operation
1611
Select the receiving apparatus for single channel operation
1612

Figure 13

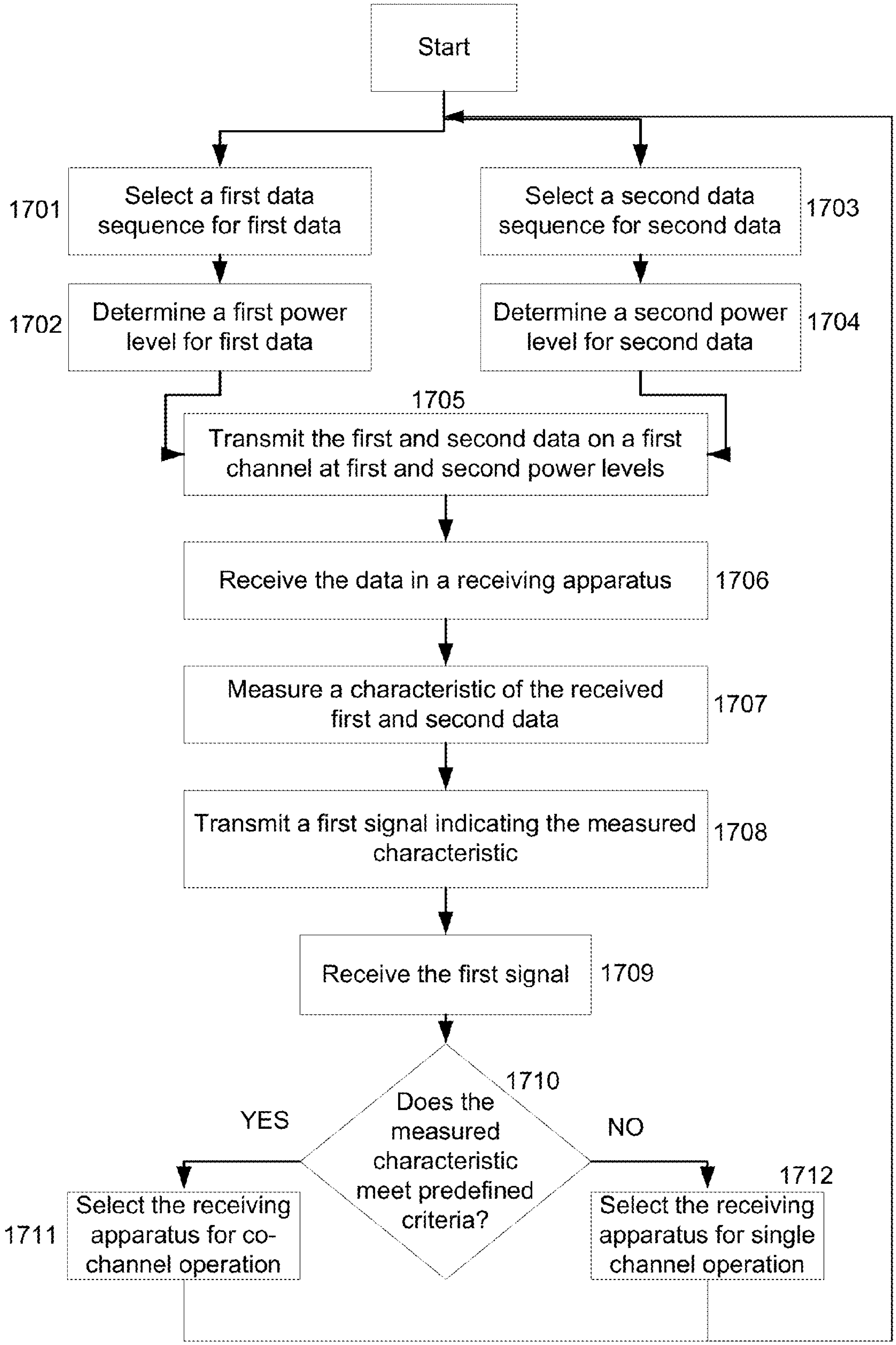

Start
1701
Select a first data sequence for first data
1702
Determine a first power level for first data
1703
Select a second data sequence for second data
1704
Determine a second power level for second data
1705
Transmit the first and second data on a first channel at first and second power levels
Receive the data in a receiving apparatus
1706
Measure a characteristic of the received first and second data
1707
Transmit a first signal indicating the measured characteristic
1708
Receive the first signal
1709
1710
Does the measured characteristic meet predefined criteria?
YES
NO
1711
Select the receiving apparatus for co-channel operation
1712
Select the receiving apparatus for single channel operation

Figure 14

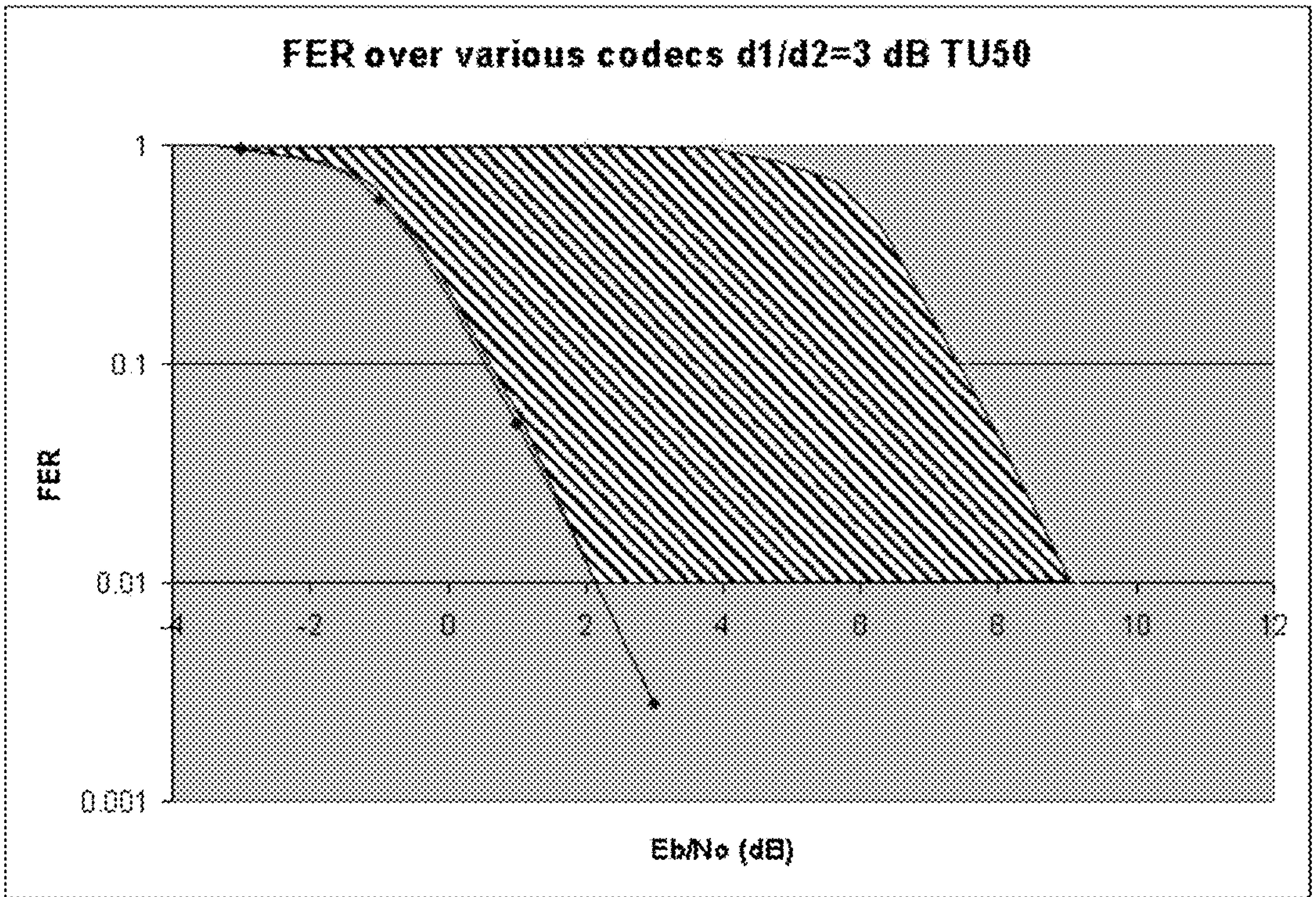

FER over various codecs d1/d2=3 dB TU50
FER
1
0.1
0.01
0.001
-4
-2
0
2
4
6
8
10
12
Eb/No (dB)

FIG. 15

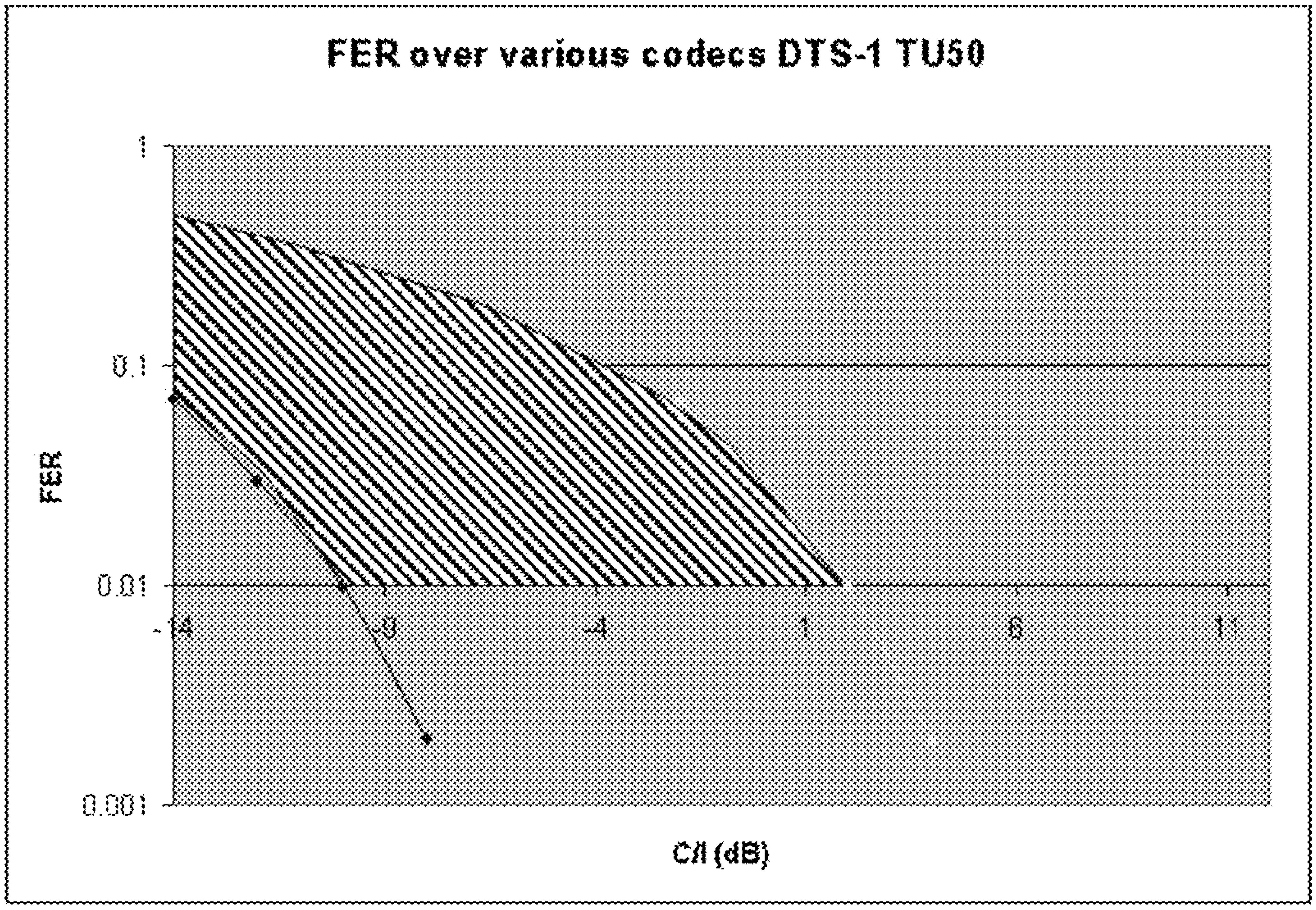

FER over various codecs DTS-1 TU50
1
0.1
0.01
0.001
FER
-14
-9
-4
1
6
11
C/I (dB)

FIG. 16

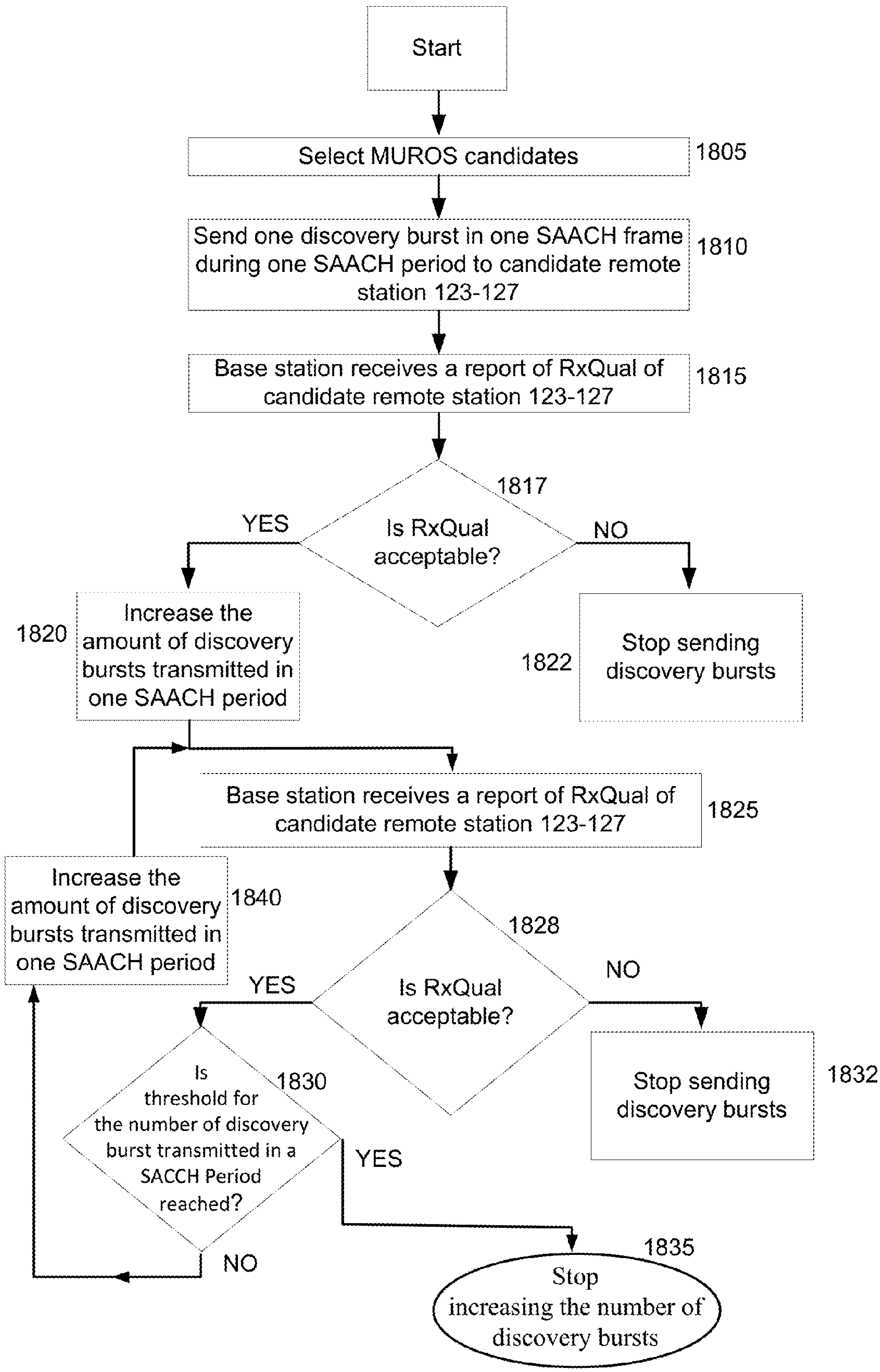

Start
Select MUROS candidates
1805
Send one discovery burst in one SAACH frame during one SAACH period to candidate remote station 123-127
1810
Base station receives a report of RxQual of candidate remote station 123-127
1815
Is RxQual acceptable?
1817
YES
NO
Increase the amount of discovery bursts transmitted in one SAACH period
1820
1822
Stop sending discovery bursts
Base station receives a report of RxQual of candidate remote station 123-127
1825
Increase the amount of discovery bursts transmitted in one SAACH period
1840
Is RxQual acceptable?
1828
YES
NO
Is threshold for the number of discovery burst transmitted in a SACCH Period reached?
1830
YES
NO
Stop sending discovery bursts
1832
Stop increasing the number of discovery bursts
1835

Figure 17

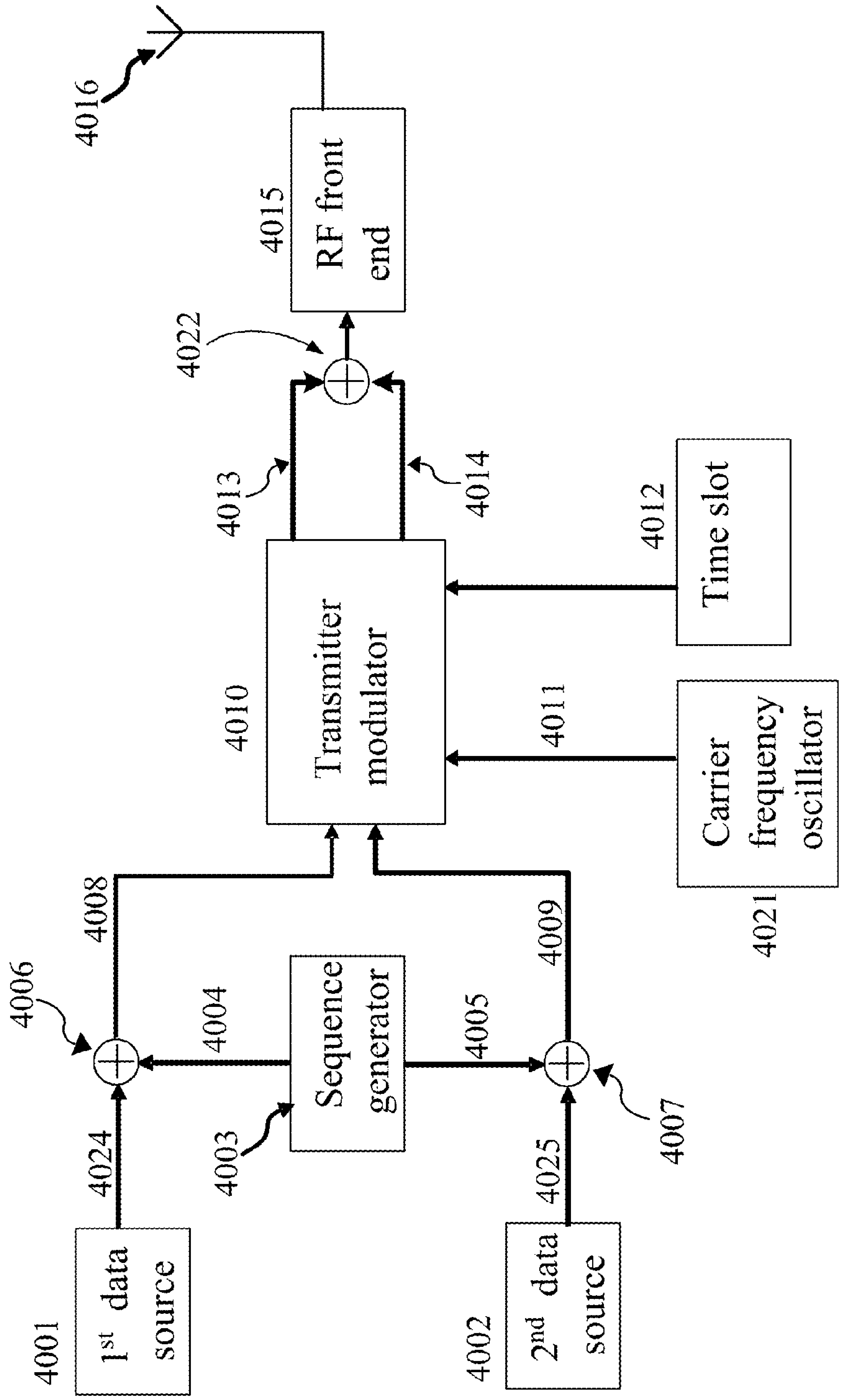

4001
1st data source
4002
2nd data source
4024
4025
4006
4007
4003
Sequence generator
4004
4005
4008
4009
4010
Transmitter modulator
4011
Carrier frequency oscillator
4021
4012
Time slot
4013
4014
4022
4015
RF front end
4016

Figure 18

Figure 19

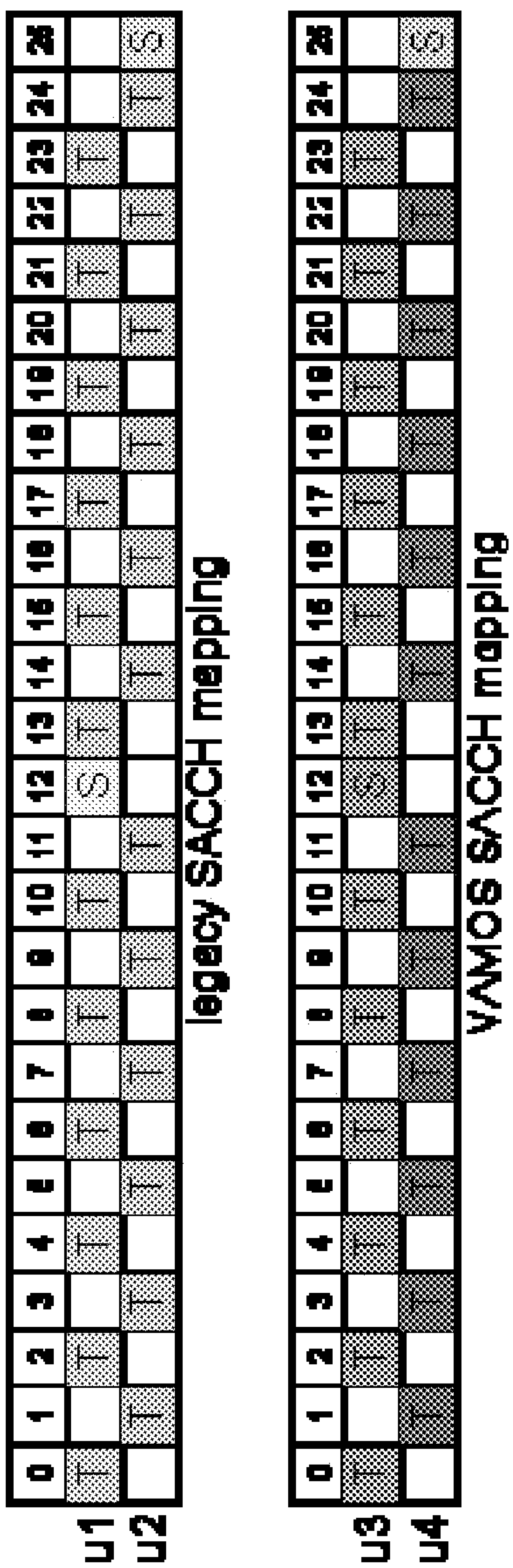
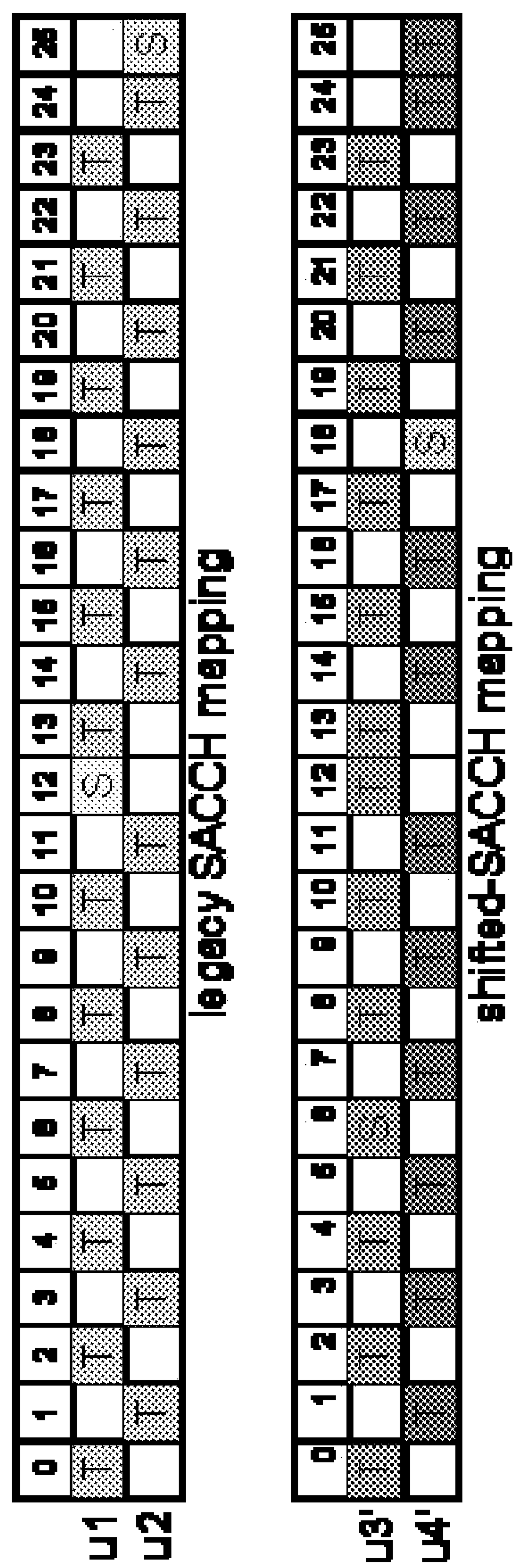


Figure 20



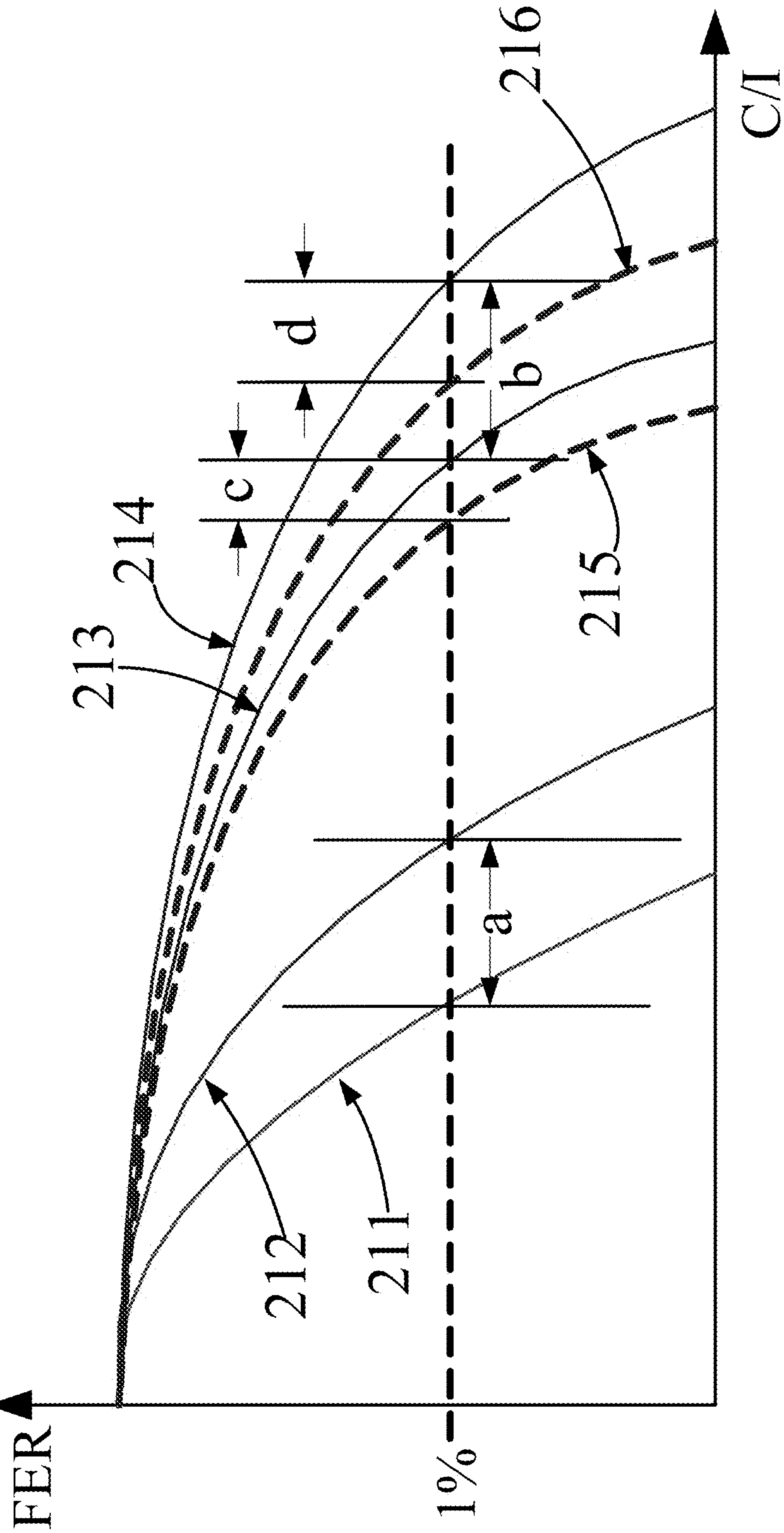


Figure 21

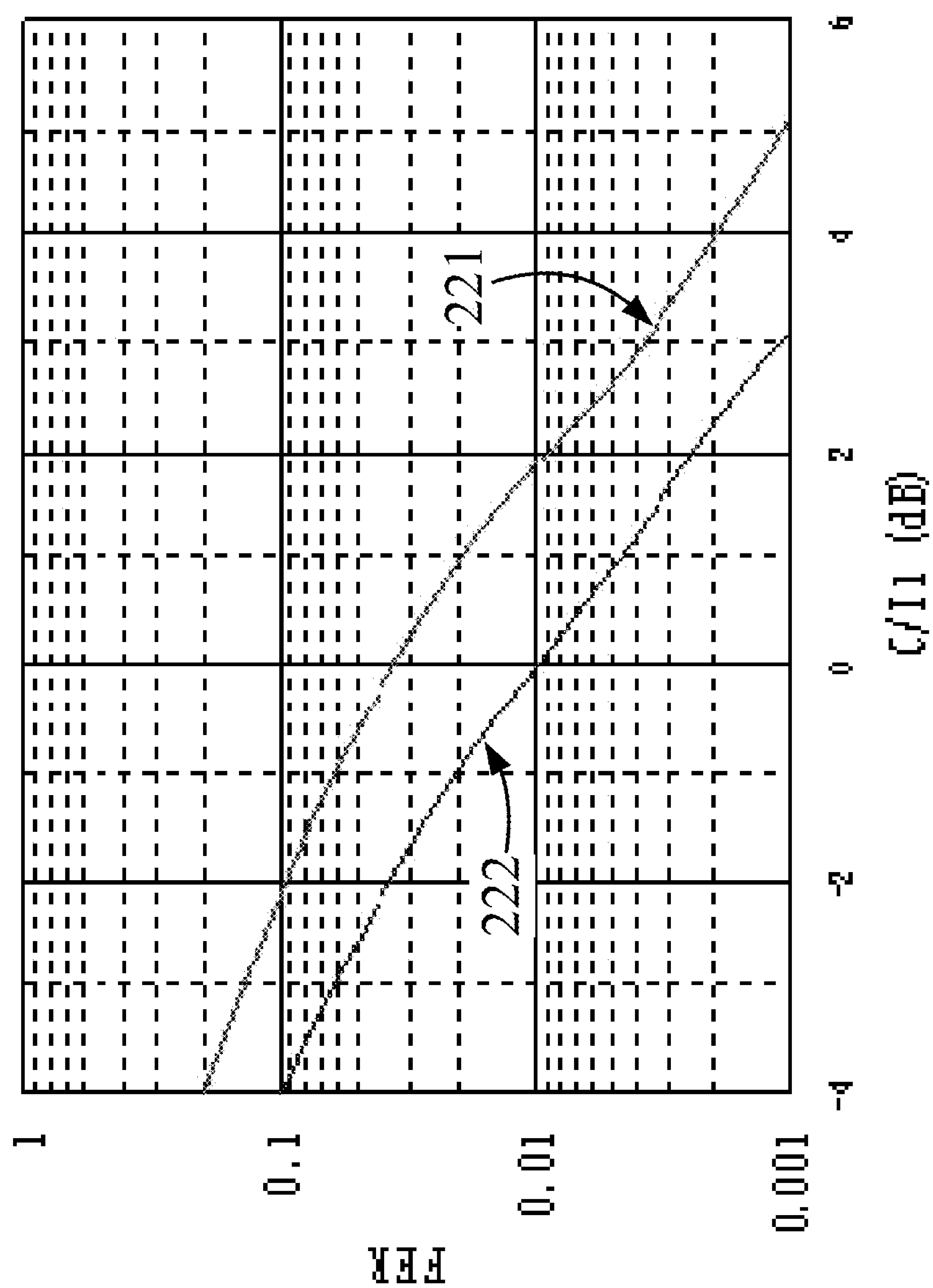


Figure 22A

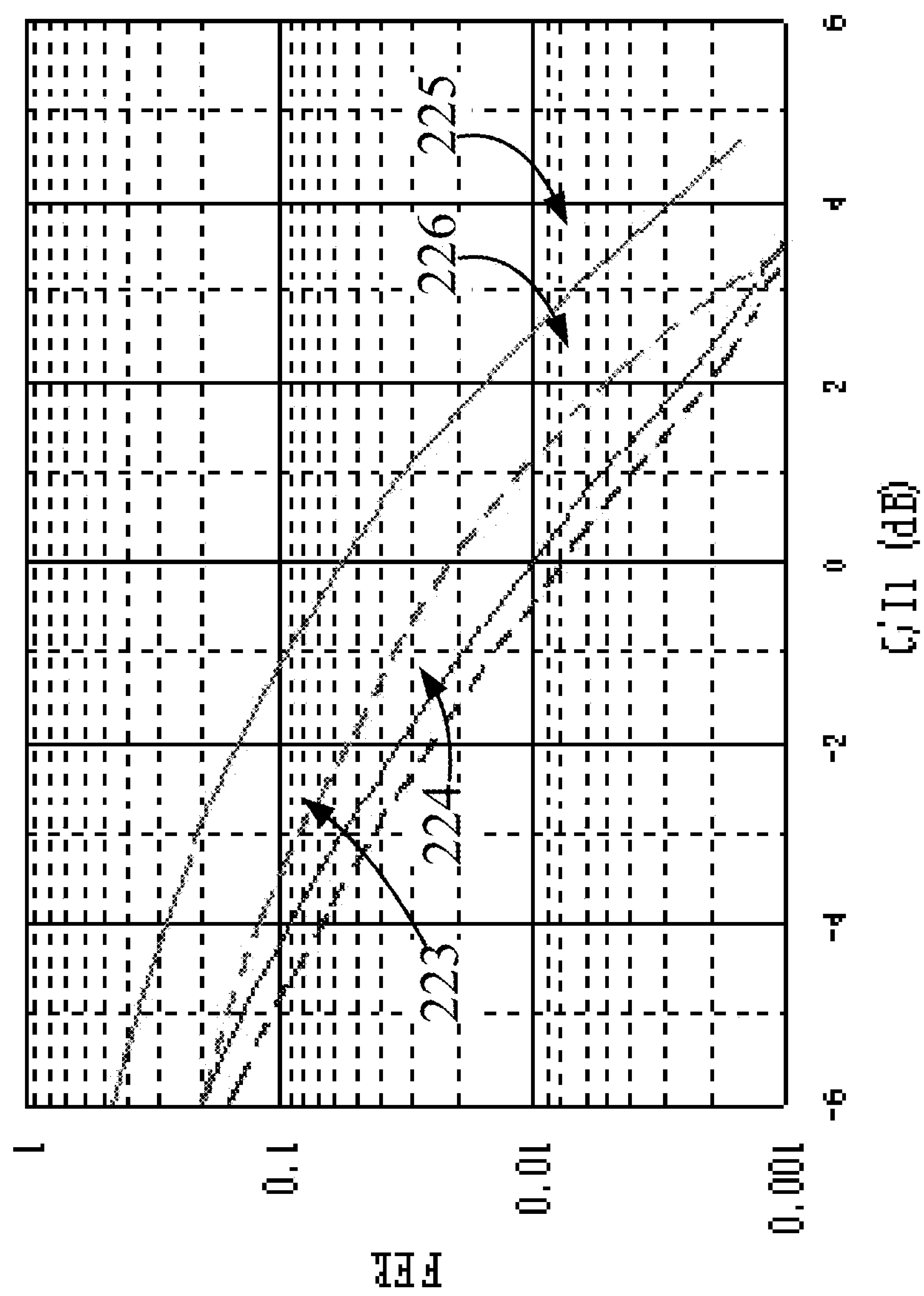


Figure 22B

TIME SHIFTING OF CO-CHANNEL DATA TRANSMISSIONS TO REDUCE CO-CHANNEL INTERFERENCE

PRIORITY CLAIM

The present Application for Patent is a continuation application of U.S. Non-Provisional application Ser. No. 13/263,983, filed Jan. 19, 2012, which is a 35 USC 371 National Phase Entry of PCT Application No. PCT/US2010/034311, which claims priority to and the benefit of U.S. Provisional Application No. 61/177,207, filed May 11, 2009. All of said applications are assigned to the assignee hereof and are hereby expressly incorporated by reference herein as if fully set forth below.

TECHNICAL FIELD

The present invention relates generally to a communication system. The present invention relates in particular to a transmitter for use in the communication system, a method of transmitting control data and information data in the communication system, and a remote station for use in the communication system.

BACKGROUND

Modern mobile cellular telephones are able to provide conventional voice calls and data calls. The demand for both types of calls continues to increase, placing increasing demands on network capacity. Network operators address this demand by increasing their capacity. This is achieved, for example, by dividing or adding cells and hence adding more base stations, which increases hardware costs. It is desirable to increase network capacity without unduly increasing hardware costs, in particular to cope with unusually large peak demand during major events such as an international football match or a major festival, in which many users or subscribers who are located within a small area wish to access the network at one time.

When a first remote station is allocated a channel for communication, a second remote station can only use the allocated channel after the first remote station has finished using the channel. Maximum cell capacity is reached when all the allocated channels are used in the cell. This means that any additional remote station user will not be able to get service. Co-channel interference (CCI) and adjacent channel interference (ACI) further limit network capacity and will be discussed below.

Network operators have addressed this problem in a number of ways, all of which use added resources and added cost. For example, one approach is to divide cells into sectors by using sectored, or directional, antenna arrays. Each sector can provide communications for a subset of remote stations within the cell and the interference between remote stations in different sectors is less than if the cell were not divided into sectors. Another approach is to divide cells into smaller cells, each new smaller cell having a base station. Both these approaches are expensive to implement due to added network equipment. In addition, adding cells or dividing cells into smaller cells can result in remote stations within one cell experiencing more CCI and ACI interference from neighboring cells because the distance between cells is reduced.

According to another approach, a base station **110**, **111**, **114** may transmit two signals on the same channel, each signal for one of two users, by operating according to methods known collectively as either Multi-User on One Slot (MUROS) or Voice services over Adaptive Multi-user on One timeSlot (VAMOS). According to the methods, a different training sequence is used for each signal.

One remote station may receive its own wanted SACCH data and unwanted SACCH data for another remote station contemporaneously on the same channel. If the one remote station receives the unwanted SACCH data at a higher power level than the level at which it receives its own wanted SACCH data, say 10 dB higher, then the unwanted SACCH data may interfere with the wanted SACCH data so that the quality of the received wanted SACCH data is degraded too much for a call to be maintained by the one remote station.

Pending international patent application having application number PCT/US2008/085569, filed on Dec. 4, 2008 and assigned to the assignee hereof, describes that newer codecs such as AMR allow lower bit rate modes to be used for channels experiencing poor radio channel conditions. There is generally no such mechanism of adjusting bit rate for signaling channels (e.g. SACCH) and therefore the signaling data is less well protected against channel degradations than traffic data. SACCH data is affected worse by co-channel operation than traffic (TCH) data because the SACCH has no redundancy, i.e., every SACCH frame must be received with few errors.

DTX is a method that improves overall efficiency of a wireless device by momentarily discontinuing the transmission of voice data when there is no significant voice input to the microphone of the wireless device (e.g. a remote station). Typically in a two-way conversation, a user of a remote station speaks during slightly less than half of the time. The duty cycle of the transmission can be cut to less than 50 percent if the transmitter signal is switched on only during periods of voice input. This improves efficiency by reducing interference and by conserving battery power.

An ongoing voice call is maintained by messaging on the slow associated control channel (SACCH). The SACCH is transmitted once during every SACCH period. DTX is operated during speech frames. The SACCH signaling frame does not use this DTX mode. That is to say, the SACCH may not get benefit from DTX in the same way that TCH does get benefit from DTX. The interference of the SACCH for a first of two paired remote stations is continuously present at the receiver of the second paired remote station.

There is therefore a need to provide improved protection of interference-sensitive data intended for a particular receiver against other interfering data not intended for the particular receiver.

SUMMARY

The features of the invention are set forthwith with particularity in the appended claims and together with advantages thereof will become clearer from consideration of the following detailed description of examples of the invention. Various changes and modifications within the scope of the invention will become apparent to those skilled in the art. The examples are described with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a block diagram of a transmitter and a receiver;

FIG. **2** shows a block diagram of a receiver unit and demodulator of the receiver shown in FIG. **1**;

FIG. **3** shows example frame and burst formats in a TDMA system;

FIG. **4** shows part of a TDMA cellular system;

FIG. **5** shows an example arrangement of time slots for a TDMA communications system;

FIG. **6** shows a simplified representation of part of a TDMA cellular system adapted to assign the same channel to two remote stations;

FIG. **7** shows example arrangements for data storage within a memory subsystem which might reside within a base station controller (BSC) of a cellular communication system;

FIG. **8** shows a flowchart of a method of assigning a channel already in use by one remote station to another remote station;

FIG. **9** is a schematic diagram of apparatus wherein the method represented by FIG. **8** resides in a base station controller;

FIG. **10** shows a receiver architecture for a remote station having enhanced co-channel rejection capability;

FIG. **11** is a schematic diagram of (a) a transmitting apparatus and (b) a receiving apparatus, together suitable for selecting a receiving apparatus for co-channel operation;

FIG. **12**A is a schematic diagram showing sequences of data frames each containing, or not containing, discovery bursts comprising co-channel data;

FIG. **12**B is a further schematic diagram showing sequences of data frames each containing, or not containing, discovery bursts comprising co-channel data.

FIG. **13** is a flow diagram of a method of selecting a receiving apparatus for co-channel operation;

FIG. **14** is a further flow diagram of a method of selecting a receiving apparatus for co-channel operation;

FIG. **15** is a graph of FER performance under different levels of signal-to-noise ratio for different codecs;

FIG. **16** is a graph of FER performance under different levels of carrier to interference for different codecs.

FIG. **17** is a flow diagram of a method of progressively increasing the number of discovery bursts within a SACCH period for a series of SACCH periods.

FIG. **18** shows an apparatus for operating in a multiple access communication system to produce first and second signals sharing a single channel.

FIG. **19** shows an example of TDMA frame mapping for traffic channel half-rate speech (TCH/HS) and slow associated control channel/Half-Rate Speech (SACCH/HS) in legacy VAMOS mode.

FIG. **20** shows an example of TDMA frame mapping for traffic channel half-rate speech (TCH/HS) and slow associated control channel/Half-Rate Speech (SACCH/HS) in Shifted-SACCH mode.

FIG. **21** is an illustration of a DTX performance analysis of the C/I used by SACCH for 1% FER versus the C/I used for TCH for 1% FER.

FIG. **22**A is a graph of the TCH and SACCH performance without DTX.

FIG. **22**B is a graph of the TCH and SACCH performance with and without DTX.

DETAILED DESCRIPTION

Interference due to other users limits the performance of wireless networks. This interference can take the form of either interference from neighboring cells on the same frequency, known as co-channel interference (CCI), discussed above, or neighboring frequencies on the same cell, known as adjacent channel interference (ACI), also discussed above.

FIG. **1** of the accompanying drawings shows a block diagram of a transmitter **118** and a receiver **150** in a wireless communication system. For the downlink, the transmitter **118** may be part of a base station, and receiver **150** may be part of a wireless device (remote station). For the uplink, the transmitter **118** may be part of a wireless device such as a remote station, and receiver **150** may be part of a base station. A base station is generally a fixed station that communicates with the wireless devices and may also be referred to as a Node B, an evolved Node B (eNode B), an access point, etc. A wireless device may be stationary or mobile and may also be referred to as a remote station, a mobile station, a user equipment, a mobile equipment, a terminal, a remote station, an access terminal, a station, etc. A wireless device may be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a subscriber unit, a laptop computer, etc.

At transmitter **118**, a transmit (TX) data processor **120** receives and processes (e.g., formats, encodes, and interleaves) data and provides coded data. A modulator **130** performs modulation on the coded data and provides a modulated signal. A transmitter unit (TMTR) **132** conditions (e.g., filters, amplifies, and upconverts) the modulated signal and generates an RF modulated signal, which is transmitted via an antenna **134**.

At receiver **150**, an antenna **152** receives the transmitted RF modulated signal from transmitter **110** together with transmitted RF modulated signals from other transmitters. Antenna **152** provides a received RF signal to a receiver unit (RCVR) **154**. Receiver unit **154** conditions (e.g., filters, amplifies, and downconverts) the received RF signal, digitizes the conditioned signal, and provides samples. A demodulator **160** processes the samples and provides demodulated data. A receive (RX) data processor **170** processes (e.g., deinterleaves and decodes) the demodulated data and provides decoded data. In general, the processing by demodulator **160** and RX data processor **170** is complementary to the processing by modulator **130** and TX data processor **120**, respectively, at transmitter **110**.

In a wireless communications system, the data is multiplexed using a multiplexing technique, so as to allow a plurality of remote stations **123-127** (each comprising a receiver **150**) to communicate with a single base station **110**, **111**, **114** (comprising a transmitter **118**). Examples of multiplexing techniques are frequency division multiplex (FDM), and time division multiplexing (TDM) or time division multiple access (TDMA). The concepts underlying these techniques will be discussed below.

Controllers/processors **140** and **180** control/direct operations at transmitter **118** and receiver **150**, respectively. Memories **142** and **182** store program codes in the form of computer software, and data used by transmitter **118** and receiver **150** respectively.

FIG. **2** of the accompanying drawings shows a block diagram of a receiver unit **154** and demodulator **160** of the receiver **150** shown in FIG. **1**. Within receiver unit **154**, a receive chain **440** processes the received RF signal and provides I and Q baseband signals, which are denoted as Ibb and Qbb. Receive chain **440** may perform low noise amplification, analog filtering, quadrature downconversion, etc. An analog-to-digital converter (ADC) **442** digitalizes the I and Q baseband signals at a sampling rate of fadc and provides I and Q samples, which are denoted as Iadc and Qadc. In general, the ADC sampling rate fadc may be related to the symbol rate fsym by any integer or non-integer factor.

Within demodulator **160**, a pre-processor **420** performs pre-processing on the I and Q samples from ADC **442**. For example, pre-processor **420** may remove direct current (DC) offset, remove frequency offset, apply automatic gain control (AGC) etc. An input filter **422** filters the samples from pre-processor **420** based on a particular frequency response and provides input I and Q samples, which are denoted as Iin and Qin to data filter **422**. Data filter **422** may filter the I and Q samples to suppress images resulting from the sampling by ADC **442** as well as jammers. Filter **422** may also perform sample rate conversion, e.g., from 24× oversampling down to 2× oversampling. A data filter **424** filters the input I and Q samples from input filter **422** based on another frequency response and provides output I and Q samples, which are denoted as Iout and Qout. Filters **422** and **424** may be implemented with finite impulse response (FIR) filters, infinite impulse response (IIR) filters, or filters of other types. The frequency responses of filters **422** and **424** may be selected to achieve good performance. In one example, the frequency response of filter **422** is fixed, and the frequency response of filter **424** is configurable.

An adjacent channel interference (ACI) detector **430** receives the input I and Q samples from filter **422**, detects for ACI in the received RF signal, and provides an ACI indicator signal to filter **424**. The ACI indicator signal may indicate whether or not ACI is present and, if present, whether the ACI is due to the higher RF channel centered at +200 KHz and/or the lower RF channel centered at −200 KHz. The frequency response of filter **424** may be adjusted based on the ACI indicator to achieve good performance.

An equalizer/detector **426** receives the output I and Q samples from filter **424** and performs equalization, matched filtering, detection, and/or other processing on the samples. For example, equalizer/detector **426** may implement a maximum likelihood sequence estimator (MLSE) that determines a sequence of symbols that is most likely to have been transmitted given a sequence of I and Q samples and a channel estimate.

In a TDMA system, each base station **110**, **111**, **114** is assigned one or more channel frequencies and each channel frequency may be used by different users during different intervals of time known as time slots. For example each carrier frequency is assigned eight time slots (which are labeled as time slots 0 through 7) such that eight consecutive time slots form one TDMA frame. A physical channel comprises one channel frequency and one time slot within a TDMA frame. Each active wireless device/user is assigned one or more time slot indices for the duration of a call. For example during a voice call, a user is allocated one time slot (hence one channel) at any instant. User-specific data for each wireless device is sent in the time slot(s) assigned to that wireless device and in TDMA data frames used for the traffic channels.

FIG. **3** of the accompanying drawings shows example frame and burst formats in a TDMA system. In a TDMA system, each time slot within a frame is used for transmitting a "burst" of data. Sometimes the terms time slot and burst may be used interchangeably. Each burst includes two tail fields, two data fields, a training sequence (or midamble) field, and a guard period (labeled GP in the figure). The number of symbols in each field is shown inside the parentheses in FIG. **3**. A burst includes 148 symbols for the tail, data, and midamble fields. No symbols are sent in the guard period. TDMA frames of a particular carrier frequency are numbered and formed in groups of 26 or 51 TDMA frames called multiframes.

For traffic channels used to send user-specific data, each multiframe in this example includes 26 TDMA frames, which are labeled as TDMA frames 0 through 25. The traffic channels are sent in TDMA frames 0 to 11 and in TDMA frames 13 to 24 of each multiframe. A control channel is sent in TDMA frame 12. No data is sent in idle TDMA frame 25, which is used by the wireless devices to make measurements for neighbor base stations **110**, **111**, **114**.

FIG. **4** of the accompanying drawings shows part of a TDMA cellular system **100**. The system comprises base stations **110**, **111** and **114** and remote stations **123**, **124**, **125**, **126** and **127**. Base station controllers **141** to **144** act to route signals to and from the different remote stations **123-127**, under the control of mobile switching centres **151**, **152**. The mobile switching centres **151**, **152** are connected to a public switched telephone network (PSTN) **162**. Although remote stations **123-127** are commonly handheld mobile devices, many fixed wireless devices and wireless devices capable of handling data also fall under the general title of remote station **123-127**.

Signals carrying, for example, voice data are transferred between each of the remote stations **123-127** and other remote stations **123-127** by means of the base station controllers **141-144** under the control of the mobile switching centres **151**, **152**. Alternatively, signals carrying, for example, voice data are transferred between each of the remote stations **123-127** and other communications equipment of other communications networks via the public switched telephone network **162**. The public switched telephone network **162** allows calls to be routed between the mobile cellular system **100** and other communication systems. Such other systems include other mobile cellular communications systems **100** of different types and conforming to different standards.

Each of remote stations **123-127** can be serviced by any one of a number of base stations **110**, **111**, **114**. A remote station **124** receives both a signal transmitted by the serving base station **114** and signals transmitted by nearby non-serving base stations **110**, **111** and intended to serve other remote stations **125**.

The strengths of the different signals from base stations **110**, **111**, **114** are periodically measured by the remote station **124** and reported to BSC **144**, **114**, etc. If the signal from a nearby base station **110**, **111** becomes stronger than that of the serving base station **114**, then the mobile switching centre (MSC) **152** acts to make the nearby base station **110**, **111** become the serving base station and acts to make the serving base station **114** become a non-serving base station. The MSC **152** thus performs a handover of the remote station to the nearby base station **110**. Handover refers to the method of transferring a data session or an ongoing call from one channel to another.

In cellular mobile communications systems, radio resources are divided into a number of channels. Each active connection (for example a voice call) is allocated a particular channel having a particular channel frequency for the downlink signal (transmitted by the base station **110**, **111**, **114** to a remote station **123-127** and received by the remote station **123-127**) and the channel having a particular channel frequency for the uplink signal (transmitted by the remote station **123-127** to the base station **110**, **111**, **114** and received by the base station **110**, **111**, **114**). The frequencies for downlink and uplink signals are often different, to allow simultaneous transmission and reception and to reduce interference between transmitted signals and received signals at either the remote station **123-127** or the base station **110**, **111**, **114**. This is known as frequency division duplex (FDD).

FIG. **5** of the accompanying drawings shows an example arrangement of time slots for a TDMA communications system. A base station **114** transmits data signals in a sequence of numbered time slots **30**, each signal being for only one of a set of remote stations **123-127** and each signal being received at the antenna of all remote stations **123-127** within range of the transmitted signals. The base station **114** transmits all the signals using time slots on an allocated channel frequency. Each channel frequency and time slot combination thus comprises a channel for communication. For example, a first remote station **124** and a second remote station **126** are both allocated the same channel frequency. The first remote station **124** is allocated a first time slot 3 and a second remote station **126** is allocated a second time slot 5. The base station **114** transmits, in this example, a signal for the first remote station **124** during time slot 3 of the sequence of time slots **30**, and transmits a signal for the second remote station **126** during time slot 5 of the sequence of time slots **30**.

The first and second remote stations **124**, **126** are active during their respective time slots 3 and 5 of time slot sequence **30**, to receive the signals from the base station **114**. The remote stations **124**, **126** transmit signals to the base station **114** during corresponding time slots 3 and 5 of time slot sequence **31** on the uplink. It can be seen that the time slots for the base station **114** to transmit (and the remote stations **124**, **126** to receive) **30** are offset in time with respect to the time slots for the remote stations **124**, **126** to transmit (and the base station **114** to receive) **31**.

This offsetting in time of transmit and receive time slots is known as time division duplexing (TDD), which among other things, allows transmit and receive operations to occur at different instances of time.

Voice signals and data signals are not the only signals to be transmitted between the base station **110**, **111**, **114** and the remote station **123**-**127**. A control channel is used to transmit data that controls various aspects of the communication between the base station **110**, **111**, **114** and the remote station **123**-**127**. Among other things, the base station **110**, **111**, **114** uses the control channel to send to the remote station **123**-**127** a sequence code, or training sequence code (TSC) which indicates which of a set of sequences the base station **110**, **111**, **114** will use to transmit the signal to the remote station **123**-**127**. In GSM, a 26-bit training sequence is used for equalization. This is a known sequence which is transmitted in a signal in the middle of every burst.

The sequences are used by the remote station **123**-**127**: to compensate for channel degradations which vary quickly with time; to reduce interference from other sectors or cells; and to synchronize the remote station's receiver to the received signal. These functions are performed by an equalizer which is part of the remote station's **123**-**127** receiver. An equalizer **426** determines how the known transmitted training sequence signal is modified by multipath fading. The equalizer may use this information to extract the desired signal from unwanted reflections of the signal by constructing an inverse filter to extract parts of the desired signal which have been corrupted by multipath fading. Different sequences (and associated sequence codes) are transmitted by different base stations **110**, **111**, **114** in order to reduce interference between sequences transmitted by base stations **110**, **111**, **114** that are close to each other.

A remote station **123**-**127** which comprises a receiver having enhanced co-channel rejection capability is able to use the sequence to distinguish the signal transmitted to it by a base station **110**, **111**, **114** from other unwanted signals transmitted by other base stations **110**, **111**, **114**. This holds true so long as the received amplitudes or power levels of the unwanted signals are below a threshold relative to the amplitude of the wanted signal. The unwanted signals can cause interference to the wanted signal if they have amplitudes above this threshold. The threshold can vary according to the capability of the remote station's **123**-**127** receiver. The interfering signal and the desired (or wanted) signal can arrive at the remote station's **123**-**127** receiver contemporaneously if, for example, the signals from the serving and non-serving base stations **110**, **111**, **114** share the same time slot for transmitting. An example of remote station **123**-**127** which has enhanced co-channel rejection capability is a remote station **123**-**127** comprising a receiver having downlink advanced receiver performance (DARP), which is described in cellular standards such as those defining the system known as Global System for Mobile communication (GSM) which is an example of a TDMA system.

A remote station **123**-**127** which has enhanced co-channel rejection capability by means of DARP, is able to use the training sequences to distinguish a first signal from a second signal and to demodulate and use the first signal, when the amplitudes of the first and second signals are substantially within, say, 10 dB of each other. Each DARP mobile station will treat the signal intended for another mobile station **123**-**127** as co-channel interference (CCI) and reject the interference.

Referring again to FIG. **4**, at remote station **124** transmissions from base station **110** for remote station **125** can interfere with transmissions from base station **114** for remote station **124**. The path of the interfering signal is shown by dashed arrow **170**. Similarly, at remote station **125** transmissions from base station **114** for remote station **124** can interfere with transmissions from base station **110** for remote station **125** (the path of the interfering signal shown by dotted arrow **182**).

TABLE 1

Row	Base station transmitting the signal	Remote station 1 receiving the signal	Channel frequency of the signal	Remote station 2 for which the signal is intended	Downlink time slot (TS) of the signal	Training sequence code (TSC) of the signal	Received power level at remote station 1	Signal category
2	114	123	41	123	5	TSC 3	-40 dBm	Wanted
3	114	124	32	124	3	TSC 3	-82 dBm	Wanted
4	110	124	32	125	3	TSC 1	-81 dBm	Interferer
5								
6	114	125	32	124	3	TSC 3	-79 dBm	Interferer
7	110	125	32	125	3	TSC 1	-80 dBm	Wanted

Table 1 above shows example values of parameters for signals transmitted by the two base stations **110** and **114** illustrated in FIG. **4**. The information in rows 3 and 4 of the table show that for remote station **124** both a wanted signal from a first base station **114** and an unwanted interferer signal from a second base station **110** and intended for remote station **125** are received and the two received signals have the same channel and similar power levels (−82 dBm and −81 dBm respectively). Similarly, the information in rows 6 and 7 shows that for remote station **125** both a wanted signal from the second base station **110** and an unwanted interferer signal from the first base station **114** and intended for remote station **124** are received and the two received signals have the same channel and similar power levels (−80 dBm and −79 dBm respectively).

Each remote station **124**, **125** thus receives both a wanted signal and an unwanted interferer signal that have similar power levels from different base stations **114**, **110**, on the same channel (i.e. contemporaneously). Because the two signals arrive on the same channel and similar power levels, they interfere with each other. This may cause errors in demodulation and decoding of the wanted signal. This interference is the co-channel interference discussed above.

The co-channel interference may be mitigated to a greater extent than previously possible, by the use of DARP-enabled remote stations **123-127**, and base stations **110**, **111**, **114** having enhanced co-channel rejection capability. DARP capability may be implemented by means of a method known as single antenna interference cancellation (SAIC) or by means of a method known as dual antenna interference cancellation (DAIC).

The DARP feature works better when the amplitudes of the received co-channel signals are similar. This situation may typically occur when each of two remote stations **123-127**, each communicating with a different base station **110**, **111**, **114**, is near a cell boundary, where the path losses from each base station **110**, **111**, **114** to each remote station **123-127** are similar.

A remote station **123-127** that is not DARP-capable, by contrast, may only demodulate the wanted signal if the unwanted co-channel interferer signal has an amplitude, or power level, lower than the amplitude of the wanted signal. In one example, it must be lower by at least 8 dB in order to allow the receiver to demodulate the wanted signal. The DARP-capable remote station **123-127** can therefore tolerate a much higher-amplitude co-channel signal relative to the wanted signal, than can the remote station **123-127** not having DARP capability.

The co-channel interference (CCI) ratio is the ratio between the power levels, or amplitudes, of the wanted and unwanted signals expressed in dB. In one example, the co-channel interference ratio could be, for example, −6 dB (whereby the power level of the wanted signal is 6 dB lower than the power level of the co-channel interferer (unwanted) signal). In another example, the ratio may be +6 dB (whereby the power level of the wanted signal is 6 dB higher than the power level of the co-channel interferer (unwanted) signal). For DARP-enabled remote stations **123-127** with good performance, the remote stations **123-127** can still process the wanted signal when the amplitude of the interferer signal is around 10 dB higher than the amplitude of the wanted signal, and. If the amplitude of the interferer signal is 10 dB higher than the amplitude of the wanted signal, the co-channel interference ratio is −10 dB.

DARP capability, as described above, improves a remote station's **123-127** reception of signals in the presence of ACI or CCI. A new user, with DARP capability, will better reject the interference coming from an existing user. The existing user, also with DARP capability, would do the same and not be impacted by the new user. In one example, DARP works well with CCI in the range of 0 dB (same level of co-channel interference for the signals) to −6 dB (co-channel is 6 dB stronger than the desired or wanted signal). Thus, two users using the same ARFCN and same timeslot, but assigned different TSCs, will get good service.

The DARP feature allows two remote stations **124** and **125**, if they both have the DARP feature enabled, to each receive wanted signals from two base stations **110** and **114**, the wanted signals having similar power levels, and each remote station **124**, **125** to demodulate its wanted signal. Thus, the DARP enabled remote stations **124**, **125** are both able to use the same channel simultaneously for data or voice.

The feature described above of using a single channel to support two simultaneous calls from two base stations **110**, **111**, **114** to two remote stations **123-127** is somewhat limited in its application in the prior art. To use the feature, the two remote stations **124**, **125** are within range of the two base stations **114**, **110** and are each receiving the two signals at similar power levels. For this condition, typically the two remote stations **124**, **125** would be near the cell boundary, as mentioned above. It is desirable to increase, by some other means, the number of active connections to remote stations that can be handled by a base station.

A method and apparatus will now be described which allows the supporting of two or more simultaneous calls on the same channel (consisting of a time slot on a carrier frequency), each call comprising communication between a single base station **110**, **111**, **114** and one of a plurality of remote stations **123-127** by means of a signal transmitted by the base station **110**, **111**, **114** and a signal transmitted by the remote station **123-127**. This supporting of two or more simultaneous calls on the same channel is known as Multi-User on One Slot (MUROS) or as Voice services over Adaptive Multi-user on One timeSlot (VAMOS). Since two training sequences may be used for signals in the same time slot on the same carrier frequency in the same cell by the same base station **110**, **111**, **114**, twice as many communication channels may be used in the cell.

FIG. **6** of the accompanying drawings shows a simplified representation of part of a TDMA cellular system adapted to assign the same channel to two remote stations **125**, **127**. The system comprises a base station **110**, and two remote stations **125**, **127**. The network can assign, via the base station **110**, the same channel frequency and the same time slot (i.e. the same channel) to the two remote stations **125** and **127**. The network allocates different training sequences to the two remote stations **125** and **127** which are both assigned: a channel frequency having frequency channel number (FCN) equal to 160; and a time slot with time slot index (TS) equal to 3. Remote station **125** is assigned a training sequence code (TSC) of 5 whereas **127** is assigned a training sequence code (TSC) of 0. Each remote station **125**, **127** will receive its own signal (shown by solid lines in the figure) together with the co-channel (co-TCH) signal intended for the other remote station **125**, **127** (shown by dotted lines in the figure). Each remote station **125**, **127** is able to demodulate its own signal whilst rejecting the unwanted signal.

DARP, when used along with the examples described herein, therefore enables a TDMA network to use a channel already in use (i.e., a channel frequency and time slot that is already in use) to serve additional users. In one example, each channel can be used for two users for full-rate (FR) speech and by four users for half-rate (HR) speech. It is also possible to serve a third or even a fourth user if the users' receivers have sufficiently good DARP performance. In order to serve additional users using the same channel, the network transmits the additional users' RF signals on the same carrier (channel frequency), using optionally different phase shifts, and assigns to the additional users the same timeslot that is in use, using a different TSC from that used by the current user. The transmitted bursts of data each comprise the training sequence corresponding to the TSC. A DARP capable receiver may detect the wanted or desired signal for that receiver while rejecting the unwanted signal for another receiver. It is possible to add third and fourth users in the same way as for the first and second users.

Single-antenna interference cancellation (SAIC) is used to reduce Co-Channel Interference (CCI). The 3G Partnership Project (3GPP) has standardized SAIC performance. The 3GPP adopted the term 'downlink advanced receiver performance' (DARP) to describe the receiver that applies SAIC.

DARP increases network capacity by employing lower reuse factors. Furthermore, it suppresses interference at the same time. DARP operates at the baseband part of a receiver of a remote station **123-127**. It suppresses adjacent-channel and co-channel interference that differ from general noise. DARP is available in previously defined GSM standards (since Rel-6 in 2004) as a release-independent feature, and is an integral part of Rel-6 and later specs. The following is a description of two DARP methods.

The first DARP method is the joint detection/demodulation (JD) method. JD uses knowledge of the GSM signal structure in adjacent cells in synchronous mobile networks to demodulate one of several interference signals in addition to the desired signal. JD's ability to demodulate interference signals allows the suppression of specific adjacent-channel interferers. In addition to demodulating GMSK signals, JD also can be used to demodulate EDGE signals. Blind interferer cancellation (BIC) is another method used in DARP to demodulate the GMSK signal. With BIC, the receiver has no knowledge of the structure of any interfering signals that may be received at the same time that the desired signal is received. Since the receiver is effectively "blind" to any adjacent-channel interferers, the method attempts to suppress the interfering component as a whole. The GMSK signal is demodulated from the wanted carrier by the BIC method. BIC is most effective when used for GMSK-modulated speech and data services and can be used in asynchronous networks.

A DARP capable remote station equalizer/detector **426** of the examples described herein and in the accompanying drawings also performs CCI cancellation prior to equalization, detection, etc. The equalizer/detector **426** in FIG. **2** provides demodulated data. CCI cancellation normally is available on a base station **110**, **111**, **114**. Also, remote stations **123-127** may or may not be DARP capable. The network may determine whether a remote station is DARP capable at the resource assignment stage, a starting point of a call for a GSM remote station (e.g. mobile station) **123-127**.

FIG. **7** of the accompanying drawings shows example arrangements for data storage within a memory subsystem which might reside within a base station controller (BSC) of a cellular communication system **100**. Table **1001** of the figure is a table of values of frequency channel numbers (FCN) assigned to remote stations **123-127**, the remote stations **123-127** being numbered. Table **1002** of the figure is a table of values of time slots wherein remote station numbers **123-127** are shown against time slot number. It can be seen that time slot number **3** is assigned to remote stations **123**, **124** and **229**. Similarly table **1003** shows a table of data allocating training sequences (TSCs) to remote stations **123-127**.

Table **1005** of the figure shows an enlarged table of data which is multi-dimensional to include all of the parameters shown in tables **1001**, **1002**, and **1003** just described. It will be appreciated that the portion of table **1005** shown in the figure is only a small part of the complete table that would be used. Table **1005** shows in addition to the allocation of frequency allocation sets, each frequency allocation set corresponding to a set of frequencies used in a particular sector of a cell or in a cell. In Table **1005**, frequency allocation set **f1** is assigned to all remote stations **123-127** shown in the table **1005** of the figure. It will be appreciated that other portions of Table **1005**, which are not shown, will show frequency allocation sets **f2**, **f3** etc. assigned to other remote stations **123-127**. The fourth row of data shows no values but repeated dots indicating that there are many possible values not shown between rows 3 and 5 of the data in table **1001**.

FIG. **8** of the accompanying drawings shows a flowchart of a method of assigning a channel already in use by one remote station **123-127** to another remote station **123-127**.

Following the start of the method **1501**, a decision is made as to whether to set up a new connection between the base station **110**, **111**, **114** and a remote station **123-127** (block **1502**). If the answer is NO, then the method moves back to the start block **1501** and the steps above are repeated. When the answer is YES (block **1502**) then a determination is made as to whether there is an unused channel, i.e. an unused time slot for any either used or unused channel frequency (block **1503**). If there is an unused time slot then a new time slot is allocated (block **1504**). The method then moves back to the start block **1501** and the steps above are repeated.

Eventually there is no longer an unused time slot (because all time slots are already used or allocated for connections), and therefore the answer to the question of block **1503** is NO, and the method moves to block **1505**. In block **1505** a used time slot is selected for the new connection to share with an existing connection.

A first used time slot (channel) having been selected for the new connection to share along with an existing connection. The existing connection uses a first training sequence. A second training sequence, different from the first training sequence, is then selected for the new connection in block **1506**. The method then moves back to the start block **1501** and the steps above are repeated.

FIG. **9** of the accompanying drawings is a schematic diagram of apparatus wherein the method represented by FIG. **8** resides in a base station controller **600**. Within the base station controller **600** are controller processor **660** and memory subsystem **650**. The steps of the method may be stored in software **680**, in memory **685**, in memory subsystem **650** or within software in memory residing in controller processor **660**, or within software or memory in the base station controller **600**, or within some other digital signal processor (DSP) or in other forms of hardware. The base station controller **600** is connected to the mobile switching centre **610** and also to base stations **620**, **630** and **640**.

Shown within memory subsystem **650** are parts of three tables of data **651**, **652**, **653**. Each table of data stores values of a parameter for a set of remote stations **123**, **124** indicated by the column labeled MS. Table **651** stores values of training sequence code. Table **652** stores values for time slot number TS. Table **653** stores values of channel frequency CHF. It can be appreciated that the tables of data could alternatively be arranged as a multi-dimensional single table or several tables of different dimensions to those shown in the figure.

The controller processor **660** communicates via data bus **670** with memory subsystem **650** in order to send and receive values for parameters to/from memory subsystem **650**.

Within controller processor **660** are contained functions that include a function **661** to generate an access grant command, a function **662** to send an access grant command to a base station **620**, **630**, **640**, a function **663** to generate a traffic assignment message, and a function **664** to send a traffic assignment message to a base station **620**, **630** or **640**. These functions may be executed using software **680** stored in memory **685**.

Within the controller processor **660**, or elsewhere in the base station controller **600**, there may also be a power control function **665** to control the power level of a signal transmitted by a base station **620**, **630** or **640**.

It can be appreciated that the functions shown as being within base station controller **600**, namely memory subsystem **650** and controller processor **660** could also reside in the mobile switching centre **610**. Some or all of the functions described as being part of base station controller **600** could equally well reside in one or more of base stations **620**, **630** or **640**.

Phase Shift

The absolute phase of the modulation for the two signals transmitted by the base station **110**, **111**, **114** may not be identical. In order to serve an additional user using the same channel (co-TCH), in addition to providing more than one TSC the network may phase shift the data symbols of the signal for the new co-channel (co-TCH) remote station with respect to the signal for the already-connected co-channel remote station(s). If possible the network may provide evenly spaced phase shift, thus improving receiver performance. For one example of two users sharing a channel, the phase difference for one user relative to another user could be 90 degrees apart. For another example in which three users share a channel, the phase difference for one user relative to another user could be 60 degrees apart. The phase shift for four users could be 45 degree apart. As stated above, the users will each use a different TSC.

Thus, for improved DARP performance, the two signals intended for the two different remote stations **123**, **124** may ideally be phase shifted by $\pi/2$ for the best channel impulse response, but a phase shift less than this will also provide adequate performance.

To provide the two signals so that their phases are offset from each other by 90 degrees, the first transmitter **1120** modulates the two signals at 90 degrees phase shift to each other, thus further reducing interference between the signals due to phase diversity.

In this way, the transmitting apparatus **1200** provides means at the base station **620**, **920** for introducing a phase difference between contemporaneous signals using the same time slot on the same frequency and intended for different remote stations **123**, **124**. Such means can be provided in other ways. For example, separate signals can be generated in the transmitting apparatus **1200** and resulting analogue signals can be combined in a transmitter front end by passing one of them through a phase shift element and then simply summing the phase shifted and non-phase shifted signals.

Power Control Aspects

Table 2 below shows example values of channel frequency, time slot, training sequence and received signal power level for signals transmitted by the two base stations **110** and **114**, and received by remote stations **123** to **127**, shown in FIG. **4**.

TABLE 2

Row	BASE STATION transmitting the signal	Remote station 1 receiving the signal	Base Station 1 serving Remote station 1	Remote station for which the signal is intended	Channel frequency.	Downlink TS	TSC	MS Received power level of signal	Signal category
2	114	126	114	126	32	5	TSC 3	-33 dBm	Wanted
3	114	123	114	123	32	3	TSC 2	-67 dBm	Wanted
4	114	124	114	124	32	3	TSC 3	-102 dBm	Wanted
5	114	123	114	124	32	3	TSC 3	-67 dBm	interferer
6	114	124	114	123	32	3	TSC 2	-102 dBm	interferer
7	114	125	110	124	32	3	TSC 3	-105 dBm	interferer
8	110	124	114	125	32	3	TSC 1	-99 dBm	interferer
9	110	125	110	125	32	3	TSC 1	-101 dBm	Wanted
10	110	127	110	127	32	3	TSC 4	-57 dBm	Wanted

The rows 3 and 4 of the table, outlined by a bold rectangle, show both remote station **123** and remote station **124** using channel frequency having index **32** and time slot 3, for receiving a signal from base station **114** but the remote stations **123**, **124** are allocated different training sequences TSC2 and TSC3 respectively. Similarly, rows 9 and 10 also show the same channel frequency and time slot being used for two remote stations **125**, **127** to receive signals from the same base station **110**. It can be seen that in each case the received power levels of the wanted signals are substantially different for the two remote stations **125**, **127** (−101 and −57 dBm respectively).

The highlighted rows 3 and 4 of Table 3 show that base station **114** transmits a signal for remote station **123** and also transmits a signal for remote station **124**. The received power levels of the wanted signals are substantially different for the two remote stations **123**, **124**. The received power level at remote station **123** is −67 dBm whereas the received power level at remote station **124** is −102 dBm. Rows 9 and 10 of Table 3 show that base station **110** transmits a signal for remote station **125** and also transmits a signal for remote station **127**. The received power level at remote station **125** is −101 dBm whereas the received power level at remote station **127** is −57 dBm. The large difference in power level, in each case, could be due to different distances of the remote stations **125**, **127** from the base station **110**. Alternatively, the difference in power levels could be due to different path losses or different amounts of multi-path cancellation of the signals, between the base station **110**, **111**, **114** transmitting the signals and the remote station **123-127** receiving the signals, for one remote station **123-127** as compared to the other remote station **123-127**.

Although this difference in received power level for one remote station **123-127** compared to the other remote station **123-127** is not intentional and not ideal for cell planning, it does not compromise the operation of the examples described herein and in the accompanying drawings.

A remote station **123-127** having DARP capability may successfully demodulate either one of two co-channel, contemporaneously received signals, so long as the amplitudes or power levels of the two signals are similar at the remote station's **123-127** antenna. This is achievable if the signals are both transmitted by the same base station **110**, **111**, **114** and the transmitted power levels of the two signals are substantially the same. Each of a first and second remote stations **123-127** receives the two signals at substantially the same power level (say within 6 dB of each other) because the path losses for the two signals between the base station and the first remote station are similar, and the path losses for the two signals between the base station and the second remote station are similar. The transmitted powers are similar if either the base station **110**, **111**, **114** is arranged to transmit the two signals at similar power levels, or the base station **110**, **111**, **114** transmits both signals at a fixed power level. This situation can be illustrated by further reference to Table 2 and by reference Table 3.

While Table 2 shows remote stations **123**, **124** receiving from base station **114** signals having substantially different power levels, on closer inspection it can be seen that, as shown by rows 3 and 5 of Table 2, remote station **123** receives two signals from base station **114** at the same power level (−67 dBm), one signal being a wanted signal intended for remote station **123** and the other signal being an unwanted signal which is intended for remote station **124**. The criteria for a remote station **123-127** to receive signals having similar power levels is thus shown as being met in this example. If mobile station **123** has a DARP receiver, it can, in this example, therefore demodulate the wanted signal and reject the unwanted signal.

Similarly, it can be seen by inspecting rows 4 and 6 of Table 2 (above) that remote station **124** receives two signals sharing the same channel and having the same power level (−102 dBm). Both signals are from base station **114**. One of the two signals is the wanted signal, for remote station **124** and the other signal is the unwanted signal which is intended for use by remote station **123**.

To further illustrate the above concepts, Table 3 is an altered version of Table 2 wherein the rows of Table 2 are simply re-ordered. It can be seen that remote stations **123** and **124** each receive from one base station **114** two signals, a wanted and an unwanted signal, having the same channel and similar power levels. Also, remote station **125** receives from two different base stations **110**, **114** two signals, a wanted and an unwanted signal, having the same channel and similar power levels.

TABLE 3

Row	BASE STATION transmitting the signal	Remote station 1 receiving the signal	Base Station 1 serving Remote station 1	Remote station for which the signal is intended	Channel frequency.	Down-link TS	TSC	MS Received power level of signal	Signal category
2	114	126	114	126	32	5	TSC 3	-33 dBm	wanted
3	114	123	114	123	32	3	TSC 2	-67 dBm	wanted
4	114	123	114	124	32	3	TSC 3	-67 dBm	interferer
5									
6	114	124	114	123	32	3	TSC 2	-102 dBm	interferer
7	114	124	114	124	32	3	TSC 3	-102 dBm	wanted
8	110	124	114	125	32	3	TSC 1	-99 dBm	interferer
9									
10	114	125	110	124	32	3	TSC 3	-105 dBm	interferer
11	110	125	110	125	32	3	TSC 1	-101 dBm	wanted
	110	127	110	127	32	3	TSC 4	-57 dBm	wanted

It is possible for a base station **110**, **111**, **114** to maintain a call with two remote stations **123-127** using the same channel, such that a first remote station **123-127** has a DARP-enabled receiver and a second remote station **123-127** does not have a DARP-enabled receiver. The amplitudes of signals received by the two remote stations **124-127** are arranged to be different by an amount which is within a range of values (in one example it may be between 8 dB and 10 dB) and also arranged such that the amplitude of the signal intended for the

DARP-enabled remote station is lower than the amplitude of the signal intended for the non-DARP-enabled remote station **124-127**.

An advantage with MUROS enabled networks is that the base station **110**, **111**, **114** may use two or more training sequences per timeslot instead of only one so that both signals may be treated as desired signals. The base station **110**, **111**, **114** transmits the signals at suitable amplitudes so that each remote station receives its own signal at a high enough amplitude and the two signals maintain an amplitude ratio such that the two signals corresponding to the two training sequences may be detected. This feature may be implemented using software stored in memory in the base station **110**, **111**, **114** or BSC **600**. For example, remote stations **123-127** are selected for pairing based on their path losses being similar and based on existing traffic channel availability. However, MUROS can still work if the path losses are very different for one remote station than for the other remote station **123-127**. This may occur when one remote station **123-127** is much further away from the base station **110**, **111**, **114** than for the other remote station.

Regarding power control there are different possible combinations of pairings. Both remote stations **123-127** can be DARP capable, or only one DARP capable. In both cases, the received amplitudes or power levels at the mobiles **123-127** may be within 10 dB of each other. However if only one remote station **123-127** is DARP capable, a further constraint is that the non-DARP remote station **123-127** has its wanted (or desired) first signal higher than the second signal (in one example, at least 8 dB higher than the second signal). The DARP capable remote station **123-127** receives its second signal no more than a lower threshold below the first signal (in one example, it is no lower than 10 dB below the first signal). Hence in one example, the amplitude ratio can be 0 dB to ±10 dB for DARP/DARP capable remote stations **123-127** or an 8 dB to 10 dB higher signal for a non-DARP/DARP pairing in favor of the non-DARP remote station **123-127**. Also, it is preferable for the base station **110**, **111**, **114** to transmit the two signals so that each remote station **123-127** receives its wanted signal at a power level above its sensitivity limit. (In one example, it is at least 6 dB above its sensitivity limit). So if one remote station **123-127** has more path loss, the base station **110**, **111**, **114** transmits that remote station's **123-127** signal at power level or amplitude appropriate to achieve this. This sets the transmitted power level. The required difference between the levels of the two signals then determines the absolute power level of that other signal.

FIG. **10** of the accompanying drawings shows a receiver architecture for a remote station **123-127** having enhanced co-channel rejection capability. The receiver is adapted to use either the single antenna interference cancellation (SAIC) equalizer **1105**, or the maximum likelihood sequence estimator (MLSE) equalizer **1106**. The SAIC equalizer is preferred for use when two signals having similar amplitudes are received. The MLSE equalizer is typically used when the amplitudes of the received signals are not similar, for example when the wanted signal has an amplitude much greater than that of an unwanted co-channel signal.

Selecting a Receiving Apparatus for Co-Channel Operation

As described above, MUROS allows more than one user on the same traffic channel (TCH) which results in enhanced capacity. This can be achieved by taking advantage of the DARP capability of remote stations **123-127**. A DARP remote station **123-127** offers more pairing opportunities when paired with another DARP remote station **123-127** because the DARP remote station can tolerate an unwanted co-channel signal at a higher power level than that of its own wanted signal, as explained above. However it is still possible to pair a non-DARP remote station **123-127** with a DARP remote station **123-127** for co-channel (i.e. MUROS) operation, as also described above. Therefore, it is advantageous to be able to select a remote station **123-127** for MUROS operation when it is not known whether or not the remote station **123-127** has DARP capability. It is also advantageous to be able to select a remote station **123-127** for MUROS operation without the need for a message to be transmitted indicating that the remote station has MUROS capability. This is because the system cannot produce such a message if the remote station **123-127** is a so-called legacy remote station which does not indicate that it has DARP capability. Apparatus and methods for selecting either a DARP or a non-DARP remote station **123-127** are described below.

If a transmitter is to transmit two co-channel signals, one for each of two receivers, then knowledge about each receiver's co-channel rejection capability is used, in order firstly to decide if both receivers are capable of handling the two co-channel signals and secondly to set the power levels of the transmitted signals in the correct ratio to ensure each receiver can handle the two signals. For example, one receiver may be non-DARP or one receiver may be further away from the transmitter than the other receiver, and both these factors determine the most suitable power levels of the transmitted signals, as described above.

A base station **110**, **111**, **114** may identify a remote station's **123-127** DARP capability by requesting the remote station's **123-127** classmark. A classmark is a declaration from a remote station **123-127** to a base station **110**, **111**, **114** of its capabilities. This is described, for example, in 24.008 of TS10.5.1.5-7 in the GERAN standards. Currently, the standards define a classmark indicative of a remote station's **123-127** DARP capability but so far, no MUROS classmark or classmark indicating support of new training sequences has been defined.

Additionally, despite the definition of a DARP classmark in the standards, the standards do not require the remote station **123-127** to send the classmark to the base station **110**, **111**, **114**. In fact, many manufacturers do not design their DARP-capable remote stations **123-127** to send the DARP classmark to the base station **110**, **111**, **114** on call setup procedures for fear that their remote stations **123-127** will automatically be assigned to noisier channels by the base station **110**, **111**, **114**, thereby potentially degrading the communication from that remote station **123-127**. It is desirable to identify whether or not a legacy remote station **123-127** is MUROS capable without using the classmark. It is currently not possible to identify with any certainty, whether a remote station **123-127** is MUROS-capable or even DARP-capable, without a prior knowledge of a remote station's DARP capability being signaled.

A base station **110**, **111**, **114** may identify MUROS-capability in a remote station **123-127** based on the International Mobile Equipment Identity (IMEI) of the remote station **123-127**. The base station **110**, **111**, **114** may establish the remote station's **123-127** IMEI by requesting it directly from the remote station **123-127**. The IMEI is unique to the remote station **123-127** and can be used to reference a database located anywhere in the network, thereby identifying the model of mobile phone to which the remote station **123-127** belongs, and additionally its capabilities such as DARP and MUROS. If the phone is DARP or MUROS capable, it will be considered by the base station **110**, **111**, **114** as a candidate for sharing a channel with another suitable remote station **123-127**. In operation, the base station **110**, **111**, **114** will build up a list of remote stations **123-127** currently connected to that base station **110**, **111**, **114** which are DARP or MUROS capable.

However, DARP or MUROS capability alone may not be a sufficient criterion for determining whether a particular remote station **123-127** can share a TDMA slot on the same frequency with another remote station **123-127**.

One way of determining the interference rejection capability of a remote station **123-127** is to send a discovery burst. This is a short radio burst in which a signal for the remote station **123-127** has a known interference pattern superimposed on it. The discovery burst comprises a signal containing a first traffic data for the remote station (e.g. basic speech) comprising a first predefined data sequence (e.g. a first training sequence) and a second (co-channel) signal comprising second data comprising a second predefined data sequence (e.g. a second training sequence), both signals at predefined power levels.

FIG. **11** of the accompanying drawings is a schematic diagram of (a) a transmitting apparatus **1200** and (b) a receiving apparatus **1240** together suitable for selecting a receiving apparatus for co-channel operation. The transmitting apparatus **1200** is configured to transmit two sets of data at predetermined power levels on a single channel. The receiving apparatus **1240** is configured: to receive the transmitted data; to measure a characteristic of the received data; and to transmit a signal indicating the characteristic. The transmitting apparatus **1200** and receiving apparatus **1240** are together suitable for selecting the receiving apparatus **1240** for co-channel operation. The features of the transmitting apparatus **1200** and receiving apparatus will now be described in more detail.

The transmitting apparatus **1200** comprises: a first transmitter **1220**; a selector comprising a processor **1215** and a memory **1216**; a first receiver **1217** coupled to the selector **1230**, the first receiver configured to receive a first signal indicating a measured characteristic of transmitted data; and a third receiver **1218**, coupled to the selector **1230**, configured to receive a second signal indicating a co-channel rejection capability of a receiving apparatus.

A first data source **1201** is configured to output first data. A first multiplexer **1203**, coupled to the first data source **1201**, receives the first data and is configured: to time division multiplex the first data by allocating a first time slot to the first data; and to output the multiplexed first data.

A first power adjuster **1205**, coupled to the first multiplexer **1203**, is configured to adjust the power level of the multiplexed first data to produce first power-adjusted data. A first modulator **1207**, coupled to the first power adjuster **1205**, is configured to modulate the first power-adjusted data onto a first channel frequency to produce first modulated data **1209**. A first amplifier **1211**, coupled to the first modulator **1207**, is configured to transmit the first modulated data **1209** to produce transmitted first data **1213**.

A second data source **1202** is configured to output second data. A second multiplexer **1204**, coupled to the second data source **1202**, receives the second data and is configured: to time division multiplex the second data by allocating a second time slot to the second data; and to output the multiplexed second data.

A second power adjuster **1206**, coupled to the second multiplexer **1204**, is configured to adjust the power level of the multiplexed second data to produce second power-adjusted data. A second modulator **1208**, coupled to the second power adjuster **1206**, is configured to modulate the second power-adjusted data onto a second channel frequency to produce second modulated data **1210**. A second amplifier **1212**, coupled to the second modulator **1208**, is configured to transmit the second modulated data **1210** to produce transmitted second data **1214**. A combiner **1219**, coupled to the first and second amplifiers **1211**, **1212**, is operable to combine the transmitted first and second data **1213**, **1214**, to produce combined transmitted first and second data. Optionally, the transmitted first and second data **1213**, **1214** are each transmitted without being combined.

The receiving apparatus **1240** comprises a second receiver **1241** operable to receive the transmitted first and/or second data and to output received data. A demodulator **1242**, coupled to the second receiver **1241**, is operable to demodulate the received data to produce demodulated data. A demultiplexer **1243**, coupled to the demodulator **1242**, is operable to time division demultiplex the demodulated data to produce demultiplexed data. A data quality estimator **1244**, coupled to the demultiplexer **1243**, is operable to measure a characteristic of the data and to output an indication of the measured characteristic. For example, the data quality estimator **1244** may measure the bit error rate (BER), or the bit error probability (BEP) of the data. A second transmitter **1245**, coupled to the quality estimator **1244**, is operable to transmit a first signal comprising the indication of the measured characteristic.

The receiving apparatus also **1240** comprises a second processor **1247**, configured to communicate with and control operation of: the demultiplexer **1243**, data quality estimator **1244**, and second transmitter **1245**. The second processor **1247** may be configured to control the operation of the second receiver **1241**, and the demodulator **1242**. A second memory **1248**, coupled to the second processor **1247**, is configured to store, and transfer to the second processor **1247**, data including instructions for the processor **1247** to use in controlling the operation of elements as described above.

The receiving apparatus **1240** also comprises a third transmitter **1246**, coupled to the second processor **1247**, operable to transmit a second signal comprising an indication of a co-channel rejection capability of the receiving apparatus **1240**.

The transmitting apparatus **1200** further comprises a first receiver **1217** and a third receiver **1218**, each coupled to the selector **1230**. The first receiver **1217** is operable to receive the first signal transmitted by the second transmitter **1245** of the receiving apparatus **1240** and to output the indication of the measured characteristic to the selector **1230**. The third receiver **1218** is operable: to receive the second signal transmitted by the third transmitter **1246** of the receiving apparatus **1240**; and to output the indication of the co-channel rejection capability to the selector **1230**.

The selector **1230** is arranged to select the receiving apparatus **1240** for co-channel operation depending on the measured characteristic, and/or to select the receiving apparatus **1240** for co-channel operation depending on the co-channel rejection capability of the receiving apparatus **1240**.

The Bit Error Probability (BEP) is measured at the remote station **123-127**. (Other parameters indicating ability of the remote station **123-127** to reject interference may also be used as discussed below). The BEP value is transmitted in the remote station's **123-127** periodic report back to the base station **110**, **111**, **114**. In the GERAN standards, for example, the BEP is represented by the values 0-31 with 0 corresponding to a probability of bit error of 25% and 31 corresponding to a probability of 0.025%. In other words, the higher the BEP, the greater the ability of the remote station **123-127** to reject interference. The BEP is reported as part of an "enhanced measurement report" or "extended report." R99 and later phones may have the capability to report BEP.

Once the burst has been sent, if the BEP of the remote station **123-127** falls below a given threshold, the remote station **123-127** may be considered to be unsuitable for MUROS operations. In simulations, a BEP of at least 25 has been shown to be an advantageous choice of threshold. It is noted that the BEP is derived by sending a burst over the channel and measuring the number of errors occurring in the burst at the remote station **123-127**.

However, the BEP on its own may not be an accurate enough measure of the qualities of the remote station **123-127** and the channel, particularly if there is a dramatic variation of error frequency across the burst. It may therefore be preferable to base the MUROS operation decision on the mean BEP taking account of the co-variance of the BEP (CVBEP). These two quantities are mandated by the standards as being present in the report which the remote station **123-127** sends to the base station **110**, **111**, **114**.

Alternatively, the determination of whether the remote station is suitable for co-channel operation could be based on the RxQual parameter returned to the base station **110**, **111**, **114** by the remote station **123-127** for one SACCH period (0.48 ms). RxQual is a value between 0 and 7 where each value corresponds to an estimated number of bit errors in a number of bursts i.e. the bit error rate (BER, see 3GPP TS 05.08). The higher the bit error rate, the higher is RxQual. Simulations have shown an RxQual of 2 or lower to be an advantageous choice of threshold for MUROS operation.

Alternatively, the parameter RxLev may be used as a selection criterion. RxLev indicates the average signal strength received in dBm. This would also be reported by the remote station **123-127** after the discovery burst. An RxLev of at least −100 dBm has been shown to be advantageous. While particular criteria for MUROS pairing have been described, it would be plain to the skilled person that many other criteria could be used instead or in combination with those identified above.

FIG. **12**A of the accompanying drawings is a schematic diagram showing sequences of data frames each containing, or not containing, discovery bursts comprising co-channel data. Three sets of 29 consecutive data frames contain discovery bursts in some of the frames. Time is represented as the horizontal axis on the drawing. Each frame is transmitted during a frame period. Each such frame period is separated from an adjacent frame period by a small vertical line on the drawing. Each frame has a frame index, from 0 to 25, as shown.

A first set of frames **1401** comprises 29 consecutive frames. During a first time interval **1410**, corresponding to a frame period of a first frame having index zero (the frame shown as a shaded box labeled zero on the drawing), a discovery burst is transmitted by the transmitting apparatus **1200** on a first channel. The first channel comprises time slot 3 of the first frame. Normal traffic bursts are transmitted during all the remaining seven of the eight time slots of the first frame, i.e. on different channels to the first channel. The transmitting apparatus may transmit the discovery burst based on a signal which the transmitting apparatus has received, the signal indicating a measured characteristic of received data.

For example, a receiving apparatus, which has received data transmitted on the first channel by the transmitting apparatus, may send a signal indicating that the measured characteristic of the received data (e.g. the BEP) has a prescribed value. The measured characteristic may have a prescribed value i.e. it may be within a prescribed range of values or it may be above some value. If the measured characteristic has the prescribed value, then the discovery burst is transmitted.

The received data may be either data which has been transmitted in a normal burst, or data which has been transmitted in a discovery burst.

During a second time interval **1411**, corresponding to the next twenty five consecutive frames having indices of 1 to 25 inclusive, normal traffic bursts are transmitted in all eight time slots of each frame, each such frame having no discovery burst. Starting with the next consecutive frame, indexed zero, the process described above for frames 0 to 25 is repeated.

Each time a frame is transmitted a receiving apparatus **1240** receives the frame of data and then measures a characteristic of the data (e.g. BEP). The receiving apparatus **1240** transmits a first signal **1260** indicating the measured characteristic.

The transmitting apparatus **1200** selects, or does not select, the receiving apparatus **1240** for co-channel operation depending on the measured characteristic.

The transmitting apparatus **1200** may select or not select the receiving apparatus **1240** depending on the measured characteristic of a single frame (e.g. frame indexed zero), or depending on the measured characteristic of several frames. The frame(s) for which the characteristic is measured could include, or not include, a frame containing a discovery burst.

If the transmitting apparatus **1200** does not select the receiving apparatus, then the transmitting apparatus **1200** may then transmit, for a prescribed period, only normal traffic bursts and not discovery bursts.

If, on the other hand, the transmitting apparatus **1200** selects the receiving apparatus **1240**, then the transmitting apparatus **1200** may again transmit, for a prescribed period, one or more discovery bursts. The transmitting apparatus **1200** may transmit a greater portion of frames containing discovery bursts than just described, as set out below.

In a second set of frames **1402**, the process described above for the first set of frames is carried out, except that a discovery burst is transmitted in both the frame indexed 0 and also the frame indexed 1. Thus the transmitting apparatus **1200** transmits a greater proportion of frames containing discovery bursts, compared to the case discussed above for the set of frames **1401**.

In a third set of frames **1403**, the process described above for the first set of frames **1401** is carried out, except that a discovery burst is transmitted in the frames indexed 0, 1 and 2. Thus the transmitting apparatus **1200** transmits a greater proportion of frames containing discovery bursts, compared to the cases discussed above for the sets of frames **1401** or **1402**.

The transmitting apparatus **1200** may continue to increase the proportion of frames containing discovery bursts frames it transmits, in relation to the total number of frames transmitted, until either all frames contain discovery bursts (hence co-channel data), or the receiving apparatus **1240** transmits a signal indicating that the measured characteristic falls outside a predefined range. For example, the BEP may be less than a predefined value.

Multiple frames containing discovery bursts may be transmitted consecutively in groups, as described above. Alternatively, the multiple frames may be transmitted non-consecutively. For example, a discovery burst may be transmitted in frames indexed 0 and 4, or several discovery bursts may be interspersed between sets of normal bursts.

FIG. **12**B of the accompanying drawings is a further schematic diagram showing sequences of data frames each containing, or not containing, discovery bursts comprising co-channel data. Such sequences would be suitable for use in a GERAN system.

Each sequence of frames, **1404** to **1408**, is a sequence of frames of SACCH data transmitted by the transmitting apparatus in a SACCH period. The sequence of frames **1404** is transmitted in SACCH 1 period (labeled SACCH 1), the sequence of frames **1405** is transmitted in SACCH 2 period (labeled SACCH 2) and so on.

Referring to each SACCH period, the first frame furthest to the left on the figure is labeled S, and is a SACCH signalling frame. The next frame has frame index **48** and contains a discovery burst. The frame with index **48** thus comprises a first time interval during which a discovery burst is transmitted. The first time interval may be considered as the period of the frame containing the discovery burst, or it may be considered as the time of duration of the discovery burst itself, i.e. a time slot. For the sake of simplicity, the first time interval is considered hereinafter as the period of the frame containing the discovery burst.

Frame 49 of the SACCH 1 period and the remainder of frames in SACCH 1 period contain no discovery burst.

During SACCH 2 period **1405**, the transmitting apparatus **1200** transmits SACCH data which does not comprise any discovery burst. The receiving apparatus receives the transmitted SACCH data. During a period corresponding to SACCH 2 period, the receiving apparatus **1240** transmits a first signal **1260**. The first signal comprises a measured characteristic (e.g. BEP) of data which has been transmitted by transmitting apparatus during SACCH 1 period and received by the receiving apparatus **1240**. The first signal comprises a message in a frame corresponding to a frame labeled S (e.g. the frame preceding frame 48 or the frame preceding frame 71).

The transmitting apparatus continues to transmit frames containing normal bursts (not discovery bursts) until, in frame indexed 48 of SACCH 3 period, the transmitting apparatus transmits a frame of data containing a discovery burst. Therefore the interval of time between frame 48 of SACCH 1 period and frame 48 of SACCH 3 period is the second time interval discussed above, during which no discovery bursts are transmitted. The second time interval may be defined as the time interval between the end of the discovery burst in frame 48 of SACCH period 1 and the beginning of the discovery burst in frame 48 of SACCH period 3. Alternatively the second time interval may be defined as the time interval between the end of frame 48 of SACCH period 1 and the beginning of frame 48 of SACCH period 3. A discovery burst is transmitted in both these frames.

During SACCH 3 period **1406**, the transmitting apparatus: transmits a frame indexed 48 which contains a discovery burst; then transmits three frames indexed 49, 50 and 51 which contain no discovery burst; and then transmits a frame indexed 52 which contains a discovery burst. The transmitting apparatus then transmits frames containing normal bursts until, in frame indexed 48 of SACCH 5 period **1408**, the transmitting apparatus transmits a frame of data containing a discovery burst.

The transmitting apparatus transmits one more frame containing a discovery burst during SACCH 3 period than for SACCH 1 period, depending on the measured characteristic which is transmitted by the receiving apparatus and received by the transmitting apparatus during a period corresponding to SACCH 2 period.

Similarly, the transmitting apparatus transmits, during SACCH 5 period, three frames which each contain a discovery burst i.e. it transmits one more frame containing a discovery burst during SACCH 5 period than for SACCH 3 period, depending on the measured characteristic which is transmitted by the receiving apparatus and received by the transmitting apparatus during a period corresponding to SACCH 4 period.

This process of adding a further frame containing a discovery burst for a later SACCH period may continue until either the measured characteristic of received data no longer meets predefined criteria or until a predetermined proportion of transmitted frames contain discovery bursts (e.g. all transmitted frames).

Table 4 below is a tabular listing of indexed SACCH data frames, for twelve SACCH periods. SACCH 1 to SACCH 8 periods are consecutive and SACCH 21 to SACCH 24 periods are consecutive. SACCH 9 to SACCH 20 periods are not shown, for simplicity. Frames containing a discovery burst are shown as having bold text and borders.

TABLE 4

	Frame index																									
SACCH 1	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	48	49	50	51	52	53	54	55	56	57	58	59	|	60	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S
SACCH 2	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	48	49	50	51	**52**	53	54	55	56	57	58	59	|	60	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S
SACCH 3	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	48	49	50	51	52	53	54	55	56	57	58	59	|	60	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S
SACCH 4	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	48	49	50	51	52	53	54	55	56	57	58	59	|	60	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S

TABLE 4-continued

SACCH 5	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	$\boxed{48}$	49	50	51	$\boxed{52}$	53	54	55	$\boxed{56}$	57	58	59	|	$\boxed{60}$	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S
SACCH 6	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	48	49	50	51	52	53	54	55	56	57	58	59	|	60	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S
SACCH 7	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	$\boxed{48}$	49	50	51	$\boxed{52}$	53	54	55	$\boxed{56}$	57	58	59	|	$\boxed{60}$	61	62	63	$\boxed{64}$	65	66	67	$\boxed{68}$	69	70	71	S
	$\boxed{72}$	73	74	75	$\boxed{76}$	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S
SACCH 8	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	48	49	50	51	52	53	54	55	56	57	58	59	|	60	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S
	. . .	. . .	. . .	. . .	. . .	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
SACCH 21	$\boxed{0}$	1	2	3	$\boxed{4}$	5	6	7	$\boxed{8}$	9	10	11	|	$\boxed{12}$	13	14	15	$\boxed{16}$	17	18	19	$\boxed{20}$	21	22	23	S
	$\boxed{24}$	25	26	27	$\boxed{28}$	29	30	31	$\boxed{32}$	33	34	35	|	$\boxed{36}$	37	38	39	$\boxed{40}$	41	42	43	$\boxed{44}$	45	46	47	S
	$\boxed{48}$	49	50	51	$\boxed{52}$	53	54	55	$\boxed{56}$	57	58	59	|	$\boxed{60}$	61	62	63	$\boxed{64}$	65	66	67	$\boxed{68}$	69	70	71	S
	$\boxed{72}$	73	74	75	$\boxed{76}$	77	78	79	$\boxed{80}$	81	82	83	|	$\boxed{84}$	85	86	87	$\boxed{88}$	89	90	91	$\boxed{92}$	93	94	95	S
SACCH 22	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	48	49	50	51	52	53	54	55	56	57	58	59	|	60	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S
SACCH 23	$\boxed{0}$	1	$\boxed{2}$	3	$\boxed{4}$	5	$\boxed{6}$	7	$\boxed{8}$	9	$\boxed{10}$	11	|	$\boxed{12}$	13	$\boxed{14}$	15	$\boxed{16}$	17	$\boxed{18}$	19	$\boxed{20}$	21	$\boxed{22}$	23	S
	$\boxed{24}$	25	$\boxed{26}$	27	$\boxed{28}$	29	$\boxed{30}$	31	$\boxed{32}$	33	$\boxed{34}$	35	|	$\boxed{36}$	37	$\boxed{38}$	39	$\boxed{40}$	41	$\boxed{42}$	43	$\boxed{44}$	45	$\boxed{46}$	47	S
	$\boxed{48}$	49	$\boxed{50}$	51	$\boxed{52}$	53	$\boxed{54}$	55	$\boxed{56}$	57	$\boxed{58}$	59	|	$\boxed{60}$	61	$\boxed{62}$	63	$\boxed{64}$	65	$\boxed{66}$	67	$\boxed{68}$	69	$\boxed{70}$	71	S
	$\boxed{72}$	73	$\boxed{74}$	75	$\boxed{76}$	77	$\boxed{78}$	79	$\boxed{80}$	81	$\boxed{82}$	83	|	$\boxed{84}$	85	$\boxed{86}$	87	$\boxed{88}$	89	$\boxed{90}$	91	$\boxed{92}$	93	$\boxed{94}$	95	S
SACCH 24	0	1	2	3	4	5	6	7	8	9	10	11	|	12	13	14	15	16	17	18	19	20	21	22	23	S
	24	25	26	27	28	29	30	31	32	33	34	35	|	36	37	38	39	40	41	42	43	44	45	46	47	S
	48	49	50	51	52	53	54	55	56	57	58	59	|	60	61	62	63	64	65	66	67	68	69	70	71	S
	72	73	74	75	76	77	78	79	80	81	82	83	|	84	85	86	87	88	89	90	91	92	93	94	95	S

During SACCH 1 period, the transmitting apparatus transmits frames of which frame 48 contains a discovery burst and the remaining frames do not contain a discovery burst.

During SACCH 2 period, the measured characteristic of the data transmitted in the SACCH 1 period is transmitted by the receiving apparatus and received by the transmitting apparatus during a period corresponding to SACCH 4 period. The measured characteristic meets the predefined criteria.

Because the measured characteristic meets the predefined criteria, during SACCH 3 period, the transmitting apparatus transmits frames of which frame 48 and frame 52 contain a discovery burst and the remaining frames do not contain a discovery burst. The process of adding frames containing discovery bursts continues, as shown for the subsequent SACCH 4 to 13 periods.

Each time the transmitting apparatus receives the measured characteristic, the transmitting apparatus selects, or does not select, the receiving apparatus for co-channel operation and, depending on the measured characteristic, the transmitting apparatus may transmit a greater proportion of frames containing discovery bursts.

It can be seen from the figure that during SACCH 13 period, alternate frames contain discovery bursts.

A final selection of the receiving apparatus results in the transmitting apparatus transmitting co-channel data during a predetermined proportion of the transmitted frames, for example all of the frames or a predetermined maximum number of frames.

After a first receiving apparatus is selected for co-channel operation, a second receiving apparatus may be selected using the procedure described above except that, to select the second receiving apparatus, discovery bursts are transmitted on the second channel, the second channel being for the data intended for the second receiving apparatus. Described above is the transmitting of discovery bursts on the first channel to select the first receiving apparatus.

Alternatively, both the first and second receiving apparatus may be selected substantially simultaneously, whereby each of the first and second data are transmitted on each channel.

Described below are methods and apparatus which illustrate how the above features may be applied to a pair of remote stations **123-127** operating using MUROS/VAMOS in a GSM or GERAN communications system.

Testing a Traffic Channel

The network may evaluate a plurality of traffic channel (TCH) candidates which two or more remote stations **123-127** may potentially use as a MUROS TCH. The selected TCH may be the TCH currently in use by a pair of users (for example when the users are served by different cells or sectors), or it may be an unused TCH that is known to have good metrics (see below). Subsequently, one of the remote stations **123-127** may be moved onto another TCH which is already in use. To increase the capacity of a cell, the network may consider a number of current remote stations **123-127** to potentially be operated in MUROS mode. Many pairs of remote stations **123-127** may be tested in parallel, possibly by the base station radio management entity. The network may enable the extended report and rely on the remote stations **123-127** reporting their BEP if they are R99 or later. If the remote stations **123-127** are pre-R99, the network may rely on the remote stations **123-127** transmitting signals indicating Rxqual and RxLev values.

Before MUROS is fully utilized on a TCH (e.g. during every or most traffic data frames), the TCH may be tested as follows. A discovery burst is transmitted by the base station **110**, **111**, **114** in place of a normal traffic (e.g. speech) burst. If the report returned by the remote station **123-127** to the base station **110**, **111**, **114** (e.g., enhanced measurement report, or extended report) indicates that the remote station **123-127** can sufficiently reject the interference caused by the co-channel signal, more discovery bursts can be sent. In one example, the discovery bursts may be sent at regular intervals, such as every SACCH period. This burst may be referred to as a MUROS discovery burst. The discovery bursts can vary in following aspects with regards to the normal (non-discovery) traffic bursts.

The amplitudes of the discovery bursts, may vary. The discovery bursts may consist of a few bits/symbols of a burst to half a burst or a whole burst.

The amount of discovery bursts sent may range from one to a few, and from non-consecutive discovery bursts to consecutive bursts.

The modulation types of the discovery burst may be different to the modulation type of the normal traffic bursts.

The modulation types of the discovery burst may vary (i.e., QPSK, alpha-QPSK, linear sum of two GMSK and high order modulations, such as 8PSK, 16QAM).

If discovery bursts are added gradually the performance of remote stations **123-127** is not degraded unacceptably during calls. It is preferable to determine a remote station's **123-127** MUROS capability without disturbing the communication. A GERAN system can make this determination because the system was designed to have some margin to combat fading since the system may not have either a fast, or a fine-step, feedback loop for physical layer power control. For a DARP-enabled remote station, such a margin is large enough that it is possible to use traffic bursts for transmitting discovery bursts to the DARP remote station, for the purpose of setting up another call. Tables 4 and 5 below show listings of consecutive transmitted frames of data transmitted by the transmitting apparatus on a first channel (channel 1) and a second channel (channel 2). The frames are indexed from 0 to 25, the sequence of frame indices then repeating from 0 to 6.

TABLE 5

Frame index	Channel 1	Channel 2
0	D1&D2	D1&D2
1	D1	D2
2	D1	D2
3	D1	D2
4	D1	D2
5	D1	D2
6	D1	D2
7	D1	D2
8	D1&D2	D1&D2
9	D1&D2	D1&D2
10	D1	D2
11	D1	D2
12	D1	D2
13	D1	D2
14	D1	D2
15	D1	D2
16	D1&D2	D1&D2
17	D1&D2	D1&D2
18	D1&D2	D1&D2
19	D1	D2
20	D1	D2
21	D1	D2
22	D1	D2
23	D1	D2
24	D1	D2
25	D1	D2
0	D1&D2	D1&D2
1	D1&D2	D1&D2
2	D1&D2	D1&D2
3	D1&D2	D1&D2
4	D1&D2	D1&D2
5	D1&D2	D1&D2
6	D1&D2	D1&D2

TABLE 4

Frame index	Channel 1	Channel 2
0	D1&D2	D2
1	D1	D2
2	D1	D2
3	D1	D2
4	D1	D2
5	D1	D2
6	D1	D2
7	D1	D2
8	D1&D2	D2
9	D1&D2	D2
10	D1	D2
11	D1	D2
12	D1	D2
13	D1	D2
14	D1	D2
15	D1	D2
16	D1&D2	D2
17	D1&D2	D2
18	D1&D2	D2
19	D1	D2
20	D1	D2
21	D1	D2
22	D1	D2
23	D1	D2
24	D1	D2
25	D1	D2
0	D1&D2	D2
1	D1&D2	D2
2	D1&D2	D2
3	D1&D2	D2
4	D1&D2	D2
5	D1&D2	D2
6	D1&D2	D2

Referring to the second column of the tables above, headed channel 1, during a first time interval corresponding to frame indexed zero, a first data D1 comprising a first data sequence, and a second (co-channel) data D2 comprising a second data sequence, are transmitted on a first channel (channel 1). During the first time interval, the second data is also transmitted on a second channel (channel 2).

The transmitted frames of data are received by the receiving apparatus **1240**. The receiving apparatus **1240** measures a characteristic of received data, based on some or all received frame(s), and transmits a signal indicating the characteristic. The signal is received by the transmitting apparatus **1200**.

During a second time interval corresponding to frames indexed 1 to 7, the first data D1 (but not the second data D2) is transmitted on the first channel (channel 1) and the second data is transmitted on the second channel (channel 2). Optionally the second data is only transmitted on channel 2 during the first time interval. This would result in loss of a portion of the second data on the second channel but it may be a simpler implementation. The transmitted frames may contain no co-channel data either depending, or not depending on the characteristic.

Depending on the characteristic (e.g. if the measured BEP is acceptable), during a third time interval corresponding to frames indexed 8 and 9, the first data D1 and the second (co-channel) data D2 are transmitted by the transmitting apparatus **1200** on the first channel (channel 1), and the second data is transmitted on a second channel (channel 2). Optionally the second data is only transmitted on channel 2 during the first time interval.

During a fourth time interval corresponding to frames indexed 10 to 15, the first data D1 (but not the second data D2) is transmitted on the first channel (channel 1) and the second data is transmitted on the second channel (channel 2).

During a fifth time interval corresponding to frames indexed 16 to 18, the first data D1 and the second (co-channel) data D2 are transmitted on the first channel (channel 1), and the second data is transmitted on a second channel (channel 2).

During a sixth time interval corresponding to frames indexed 19 to 25, the first data D1 (but not the second data D2) is transmitted on the first channel (channel 1) and the second data is transmitted on the second channel (channel 2).

During a seventh time interval corresponding to frames indexed 0 to 6, the first data D1 and the second (co-channel) data D2 are transmitted on the first channel (channel 1), and the second data is transmitted on a second channel (channel 2).

Thus, depending on the measured characteristic of received data, the second data is either sent, or not sent, on the same channel as the first data. Additionally, as shown in table 4, the second data is sent on the same channel as the first data during a time interval which depends on the measured characteristic of received data. For example, if the BEP reported for received frames 0 to 7 of table 4 (or for only frame 0) is within a predetermined range, then both first and second (co-channel) data are transmitted in frames 8 and 9. The time interval for sending co-channel data (i.e. the number of frames in this example) may be set to increase with time so long as the measured characteristic remains within the predetermined range and until a target proportion of frames contain co-channel data.

Thus, Table 4 shows a listing of consecutive transmitted frames of data in which: a portion of the frames transmitted on channel 1 contain discovery bursts i.e. co-channel data (first data D1 for a first receiving apparatus and second data D2 for a second receiving apparatus); and all of the frames transmitted on channel 2 contain only the second data D2. The discovery bursts are used, as described above, to select, or not select, the first receiving apparatus.

Table 5 shows a listing of consecutive transmitted frames of data in which: a portion of the frames transmitted on channel 1 contain discovery bursts and all of the frames transmitted on channel 2 contain only the second data D2; and additionally a portion of the frames transmitted on channel 2 contain discovery bursts. For simplicity, the discovery bursts are shown as being transmitted in the same frames for both channel 1 and channel 2, however the discovery bursts may be transmitted in different frames for channel 2 than for channel 1.

The discovery bursts as shown in table 5 are used as described above: to select or not select the first receiving apparatus **1240**; and additionally to select or not select a second receiving apparatus **1240**.

FIG. **13** of the accompanying drawings is a flow diagram of a method of selecting a receiving apparatus **1240** for co-channel operation. A first data sequence is selected for first data (block **1601**). The first data sequence comprises a first training sequence. A first power level is determined for transmitting the first data (block **1602**). A second data sequence is selected for second data (block **1603**). The second data sequence comprises a second training sequence. A second power level is determined for transmitting the second data (block **1604**). The equalizer **1105** of the receiving apparatus **1240** can use the first training sequence to distinguish the first signal from the second signal, and can use the second training sequence to distinguish the second signal from the first signal.

The first and second data are transmitted on a first channel at the respective first and second power levels (block **1605**). The transmitted data is received in the receiving apparatus **1240** (block **1606**) and a characteristic of the data, BEP, is measured (block **1607**). The receiving apparatus **1240** transmits a signal indicating the BEP (block **1608**). The transmitting apparatus **1200** receives the signal (block **1609**). A determination is made (block **1610**) of whether the measured characteristic meets predefined criteria, for example, does the BEP fall within a predefined limit? If the measured characteristic meets the predefined criteria, the receiving apparatus **1240** is selected for co-channel operation (block **1611**). If the measured characteristic does not meet the predefined criteria, the receiving apparatus **1240** is not selected for co-channel operation (block **1612**) but is selected for single channel operation.

FIG. **14** of the accompanying drawings is a further flow diagram of a method of selecting a receiving apparatus **1240** for co-channel operation. In this flow diagram, the steps are the same as those shown in FIG. **13**, except that in block **1707**, a characteristic of the first and second data (not only the first data) is measured. In block **1607** of FIG. **13**, a characteristic of only the first data is measured.

Selection of Speech Codec

Another consideration is that the CCI rejection of a DARP capable remote station **123-127** will vary depending on which speech codec is used. For example, the ratio of transmitted powers for two paired remote stations **123-127** may also be affected by the selection of codecs. For example, a remote station **123-127** using a low codec rate (such as AHS 4.75) would be able to still operate while receiving less power (such as 2 dB) than if the remote station **123-127** used a higher codec rate (such as AHS5.9), due to the coding gain. To find the better codecs for a pair of remote stations **123-127**, a lookup table may be used to find suitable codecs for the pair.

Thus, the network may assign different downlink power levels according to a) the distance from the base station **110**, **111**, **114** to the remote station **123-127**, and b) the codecs used.

FIG. **15** of the accompanying drawings is a graph of FER performance under different levels of signal-to-noise ratio (Eb/No) for different codecs.

FIG. **16** of the accompanying drawings is a graph of FER performance under different levels of carrier to interference (C/I) for different codecs.

It may be better if the network finds co-channel users who are at a similar distance from the base station **110**, **111**, **114**. This is due to the performance limitation of CCI rejection. If one signal is stronger compared to a weaker signal, the weaker signal may not be detected due to the interference to the weaker signal by the stronger signal, if the ratio of powers between weaker and stronger signal is too great. Therefore, the network may consider the distance from the base station **110**, **111**, **114** to new users when assigning co-channels and co-timeslots. The following described procedures would allow the network to minimize the interference to other cells.

Remote stations **123-127** may be selected as candidates for MUROS operation based on, for example, the RxLev reported by each remote station **123-127**, and a traffic assignment (TA) made to the candidate MUROS remote stations **123-127**. The network can dynamically determine possible MUROS pairing groups of remote stations **123-127**. For example, if a non-DARP capable remote station **123-127** is further away from a serving base station **110**, **111**, **114** than a DARP capable remote station **123-127**, it may be possible to pair the two remote stations **123-127** as described above, such that the transmitted power levels are different for the two remote stations **123-127**.

To dynamically pair groups of remote stations **123-127**, the network may maintain a dynamic database of the above information (e.g. range, RXLEV, etc.) for remote stations **123-127** in the cell and prepare to make changes to the pairings when the RF environment changes. These changes include: new pairing, de-pairing and re-pairing either both of a pair of remote stations **123-127**, or just one of them. These changes are determined by: changes of power ratios between the paired MUROS remote stations **123-127**; and also changes of codecs used by each MUROS caller.

As stated above, the metrics RXqual/BEP and RxLev may be used to measure the effect of the discovery bursts. For those discovery bursts that have an associated increase of Rxqual or decrease of BEP (i.e. a degraded quality of received data at the remote station **123-127**), the remote station **123-127** at that moment may not be suitable for MUROS on the TCH candidate on which the discovery bursts are transmitted. On the other hand, if the BEP/Rxqual for the discovery burst is not much worse than for the normal bursts, then MUROS may be suitable for that candidate TCH.

For a 0 dB MUROS discovery burst (in which the co-channel data is transmitted at the same power level or amplitude as the normal traffic data), the RxLev metric could have a 3 dB increase during the SACCH period when the discovery bursts are sent. Such a test may also be used with different codecs. For example, using codec ASH5.9 in a DARP capable phone **123-127**, and assigning 0 dB MUROS power ratio between the two MUROS signals in the discovery burst, would cause minimal degradation of the Rxqual/BEP metrics. On the other hand, a non-DARP capable phone **123-127**, in the same conditions, may indicate a drop in the Rxqual metric even after only one discovery burst has been transmitted. Also, for a discovery burst which has a duration of one SACCH period (0.48 sec), the RxLev metric may be 3 dB higher (due to 0 dB co-channel power ratio) than for the normal, non-discovery bursts.

For those remote stations **123-127** that are DARP capable, further information about their capability to pair with non-DARP capable and DARP capable phones **123-127** may be obtained. This information may include: the power ratio between the co-TCH users; the codecs that can be applied to each co-TCH users in their condition; or the training sequence to be used. Hence, a co-TCH can be adapted to wide range of MUROS remote stations **123-127**.

It is possible to obtain a sustainable power ratio between two remote stations **123-127** which can be paired on a MUROS co-TCH by a step by step increase in power of signal for the prospective co-TCH user and by gauging a suitable ratio where the metrics indicate an acceptable performance. For those remote stations **123-127** where the power ratio is below a certain value, say −4 dB, it is possible to pair that remote station **123-127** with a non-DARP capable phone **123-127**. For those remote stations **123-127** where the power ratio is around 0 dB, then a DARP capable remote station **123-127** can be used to pair with another DARP remote station.

For those remote stations **123-127** that are suitable or have been on MUROS calls, similar estimations apply so that the network may switch the remote stations **123-127** back to normal operation when conditions indicate to do so. The examples described herein and in the accompanying drawings work with legacy remote stations **123-127**, as there is nothing new that a remote station **123-127** will do when paired with a MUROS capable remote station **123-127**. The legacy DARP remote station **123-127** just operates as if in normal operation without realizing that a smart network is using its DARP capability for good capacity gain in the cell.

Description of Prescribed Discovery Bursts

An ongoing voice call is kept alive and maintained by a SACCH. The base station **110**, **111**, **114** relies on the remote station's **123-127** SACCH report containing such information as, in one example, the value of RXQual of a remote station **123-127**, to decide what to do next. Each SACCH period/frame is 104 frames and 480 ms long. Enhanced power control (EPC) can reduce the period/frame length to 26 frames and 120 ms long. The remote station **123-127** is used to report previous SAACH period performance, so there is 480 ms or 120 ms delay. A call is dropped if a number of SACCH reports are missing. An operator may set the value or threshold of missing SAACH reports where a call is dropped. For example, losing 25 SACCH frames is likely to drop the call. On the other hand, a call won't be dropped if one SACCH frame is lost. A method may be used to make a call drop decision.

Using EPC to determine if a remote terminal **123-127** is MUROS capable may be quicker because its period/frame length is shorter. Both EPC and the normal SACCH frame can be used by the network when sending discovery bursts to determine if a remote terminal **123-127** is MUROS capable. Below are some examples of sending discovery bursts during a normal SACCH period to describe the points of operation. The same method may be applied to an EPC case.

In order not to cause an unnecessary dropped call, the discovery bursts may be applied lightly. i.e., one discovery burst per SACCH period, to start with. Thus, at the beginning, only during 1 of the 104 frames in a SAACH period will a discovery burst be sent. The number of frames when discovery bursts are sent is then ramped up. MUROS may be applied to those remote stations **123-127** that have no problem handling discovery bursts sent during all SACCH frames (104) in a SACCH period. In one example, it may be helpful to send discovery bursts to multiple SACCH frames to make sure the remote station **123-127** is good enough for MUROS operation.

FIG. **17** is a flow diagram of a method of progressively increasing the number of discovery bursts within a SACCH period for a series of SACCH periods. The method is low risk and avoids bad voice quality and dropped calls.

Initially a base station **110**, **111**, **114** selects MUROS candidate remote stations from remote stations that report good Rxqual values, e.g. Rxqual=0 (step **1805** of FIG. **17**).

The base station's transmitting apparatus sends just one discovery burst during one frame of the 104 frame SAACH period (step **1810** of FIG. **17**). For example one discovery burst is sent during TCH frame 48. The reasons to start from frame 48 are: it is the first burst of a speech block; and the base station **110**, **111**, **114** may use some time to process the last SACCH data received from the remote station. Frame 48 is near the middle of the SAACH period. This gives the base station **110**, **111**, **114** enough time to analyze the remote station's **123-127** report during the last SACCH period, before the next SAACH period starts.

During the next SACCH period, the base station **110**, **111**, **114** receives a report of the RxQual of the remote station **123-127** during the last SACCH period (step **1815**). Other measured characteristics such as BEP or RxLev may be identified in the report. No discovery bursts are sent in the next SACCH period when a reference RxQual is reported to the base station **110**, **111**, **114**.

Next, the base station **110**, **111**, **114** determines if the RXQual is acceptable (step **1817**). If the Rxqual is acceptable (for example, Rxqual<=1) the base station **110**, **111**, **114** transmits two discovery bursts during the next SAACH period (step **1820**). For example, discovery bursts may be sent during TCH frames 48 and 52. This procedure avoids sending two discovery bursts in one speech block (4 frames) at an early stage. If the discovery bursts cause speech data errors on this TCH, the speech quality is impacted less if the two discovery bursts are not sent in one speech block.

The next SACCH period (SACCH (N+1) period) is used to report RxQual of the remote station **123-127** for this SACCH period (SACCH N period) to the base station **110**, **111**, **114** (step **1825**). If the RxQual is not acceptable, no more discovery bursts are sent (step **1822**).

A progressively increasing number of discovery bursts are transmitted by the base station **110**, **111**, **114** to the remote station **123-127** during a SAACH period until a threshold is reached. In one example, the threshold is that the first burst of all 24 speech blocks in a SACCH frame comprises a discovery burst. In another example, discovery bursts are transmitted during all 104 frames of a SAACH period. A possible sequence of steps for transmitting discovery bursts is: 1:2:4:8:24, which is 480×2×5=4800 msec. Therefore the first stage uses about 5 seconds to determine the good MUROS candidates which will be put on a short list.

During the next SACCH period, the base station **110**, **111**, **114** receives a report of the RxQual of the remote station **123-127** during the last SACCH period (step **1825**).

A determination is made of whether the RxQual is still acceptable (step **1828**) If the remote station's **123-127** Rxqual is still acceptable, then a check is made of whether the threshold reached concerning the maximum number of discovery bursts to transmit during a SAACH (step **1830**). If RxQual is not acceptable, no more discovery bursts are transmitted (step **1832**). If the threshold is reached, the proportion of frames containing discovery bursts is no longer increased. (step **1835**). If the threshold is not reached, the number of discovery bursts in one SAACH period is increased and the process returns to step **1825**, to await the next reporting of RXQual. (step **1840** of FIG. **17**).

In one example, for those remote stations **123-127** that do not have Rxqual<3, discovery is stopped, and they are dropped from the short list of MUROS capable remote stations **123-127**. The reference SACCH period may be a good reference period in which to compare a remote station's **123-127** Rxqual with a remote station's **123-127** Rxqual during a SAACH period in which discovery bursts were sent. One reason is that the environment of the remote station **123-127** may change such that the RxQual deteriorates independently of any discovery bursts. That may happen when remote station **123-127** receives strong interference from other remote stations **123-127** or the remote station's signal experiences bad multipath fading.

The ¼ discovery burst rate (one discovery burst transmitted every 4th frame) shown in SAACH period #11 is generally a good indication of MUROS candidates. From there, the base station **110**, **111**, **114** may transmit twice as many discovery bursts in SACCH period #13 (one discovery burst transmitted every 2nd frame), or the base station **110**, **111**, **114** may change the power level of the discovery bursts.

FIG. **18** of the accompanying drawings shows an apparatus for operating in a multiple access communication system to produce first and second signals sharing a single channel. A first data source **4001** and a second data source **4002** (for a first and a second remote station **123-127**) produce first data **4024** and second data **4025** for transmission. A sequence generator **4003** generates a first sequence **4004** and a second sequence **4005**. A first combiner **4006** combines the first sequence **4004** with the first **4024** data to produce first combined data **4008**. A second combiner **4007** combines the second sequence **4005** with the second data **4025** to produce second combined data **4009**.

The first and second combined data **4008**, **4009** are input to a transmitter modulator **4010** for modulating both the first and the second combined data **4008**, **4009** using a first carrier frequency **4011** and a first time slot **4012**. In this example, the carrier frequency may generated by an oscillator **4021**. The transmitter modulator outputs a first modulated signal **4013** and a second modulated signal **4014** to a combiner **4022** which combines the modulated signals **4013**, **4014** to provide a combined signal for transmission. A RF front end **4015**, connected to the combiner **4022**, processes the combined signal by upconverting it from baseband to an RF (radio frequency) frequency. The combined upconverted signal is sent to antenna **4016** where the upconverted signal is transmitted via electromagnetic radiation. The combiner **4022** may be a part of either the transmitter modulator **4010** or the RF front end **4015** or a separate device.

DTX Performance of SACCH for VAMOS

The robustness of the associated control channel (ACCH) may influence network voice capacity because the ACCH (unlike the traffic channel, TCH) has no built-in redundancy. That is, all ACCH data must be received with few errors in order for a dedicated data session, for example a voice session, to continue. The ACCH comprises the slow associated control channel (SACCH) and the fast associated control channel (FACCH).

A communications network may communicate with more than one remote station on the same channel. In order to do this, a first signal is transmitted at a first power level, the signal containing first data for a first remote station, and a second signal is transmitted on the same channel, contemporaneously with the first signal and at a second power level, the second signal containing second data for a second remote station. The first and second data comprise first and second SACCH data respectively.

The network communicates in this way in two circumstances. In a first circumstance a first base station transmits the first signal and a second base station transmits the second signal. In a second circumstance the first base station transmits both the first and second signals. In the second circumstance the first and second signals may be combined in the transmitter and transmitted as one signal.

A base station **110**, **111**, **114** may transmit the first and second signals on the same channel by operating according to methods known collectively as either Multi-User on One Slot (MUROS) or as Voice services over Adaptive Multi-user on One timeSlot (VAMOS). According to the methods, a different training sequence is used for each signal. This principle of operation may be extended to more than two remote stations.

Each remote station receives the first and second SACCH data contemporaneously on the same channel. If the second remote station receives the first SACCH data at a higher power level than the level at which it receives the second SACCH data, say 10 dB higher, then the first SACCH data may interfere with the second SACCH data at the second remote station to an extent whereby the quality of the received second SACCH data is degraded too much for a call to be maintained by the second remote station.

By offsetting in time the first SACCH data from the second SACCH data, the above problem can be largely avoided because the second remote station receives the first SACCH data and second SACCH data at different times and therefore the first SACCH data does not interfere with the second SACCH data, at the second remote station.

Furthermore, if the first and second SACCH data are offset as described above, then the power level of the second SACCH data may be increased so that the second SACCH data still does not interfere with the first SACCH data. This is advantageous to the second remote station if the second remote station experiences degradation of the quality of its received second SACCH data. For example, the second remote station may be subject to greater path loss from the base station than for the first remote station, and may also experience a sudden or momentary fade due to multipath.

DTX is a method that improves overall efficiency of a wireless device by momentarily discontinuing the transmission of voice data when there is no significant voice input to the microphone of the wireless device (e.g. a remote station). Typically in a two-way conversation, a user of a remote station speaks during slightly less than half of the time. The duty cycle of the transmission can be cut to less than 50 percent if the transmitter signal is switched on only during periods of voice input. This improves efficiency by reducing interference and by conserving battery power.

An ongoing voice call is maintained by messaging on the slow associated control channel (SACCH). The base station **110**, **111**, **114** relies on the remote station's **123-127** SACCH report containing such information as, for example, the value of RXQual of a remote station **123-127**, to decide what to do next. The SACCH is transmitted once during every SACCH period. Each SACCH period is 104 frames long (480 ms) unless enhanced power control (EPC) is used, in which case the period length is reduced to 26 frames (120 ms). The remote station **123-127** transmits a report, in a SACCH period, indicating the performance of the SACCH during the previous SACCH period. Therefore there is a 480 ms or 120 ms delay in reporting.

The network and may apply a time offset between communication signals of neighbor cells (Step **1530**), especially between those signals that have significant co-channel interference (CCI) or adjacent channel interference (ACI). For example, the time offset may be an integer number of data frame durations. As a result, even though the SACCH is transmitted by a base station with greater power than the power of the TCH, only one cell in a cluster of cells is raising the power level of its SACCH at any time.

The time offset may be different for each of several remote stations, each remote station's SACCH therefore being offset in time from the SACCHs of the other remote stations. In order to apply frame offsets in this way, the network may synchronize the transmissions of base stations, for example by several base stations utilizing a common time reference and each base station applying a time offset which is relative to the common time reference.

The offsetting of the SACCH transmissions for two or more remote stations, described above, thus partly overcomes the problem that co-channel operation degrades the quality of the SACCH data received by at least one of the remote paired remote stations **123-127**, due to interference from data for the other remote station **123-127**. SACCH data is affected worse by co-channel operation than traffic (TCH) data because the SACCH has no redundancy, i.e., every SACCH frame must be received with few errors.

More particularly, a time offset may be applied to all the data, or only to the SACCH data (e.g. not to traffic data), or at least to the SACCH data transmitted by a base station. Described below is an example implementation wherein first and second SACCH data are offset from one another in time.

DTX Performance Analysis

FIG. **19** shows an example of TDMA frame mapping for traffic channel half-rate speech (TCH/HS) and slow associated control channel/Half-Rate Speech (SACCH/HS) in legacy VAMOS mode.

FIG. **20** shows an example of TDMA frame mapping for traffic channel half-rate speech (TCH/HS) and slow associated control channel/Half-Rate Speech (SACCH/HS) in Shifted-SACCH mode.

For instance, there are 4 users (u**1** to u**4**) reusing 2 half-rate (HR) channels. The users u**1** and u**2** are legacy remote stations **123-127** using the legacy TDMA frame mapping. The users u**3** and u**4** (or u**3'** and u**4'**) are two VAMOS enabled remote stations **123-127**. The differences between u**3** and u**3'**(or between u**4** and u**4'**) are that they using different frame mapping methods. The former uses a legacy frame mapping method, the latter uses the Shifted-SACCH mapping method. The remote stations **123-127** u**1** and u**3** (or u**3'**) are two paired users in one half-rate (HR) channel. The remote stations **123-127** u**2** and u**4** (or u**4'**) are two paired users in the other HR channel.

Discontinuous transmission (DTX) during speech inactivity is applied in various cellular speech communication systems. This is a technique in essence to turn off the transmission during periods of speech silence. The purpose is to reduce interference caused to other users concurrently transmitting on the air interface and to save battery power in the remote stations **123-127**. DTX is operated during speech frames. The SACCH signaling frame does not use this DTX mode. That is to say, if the paired MUROS users employ the mapping method in legacy VAMOS mode as shown in FIG.

19, the SACCH may not get benefit from DTX in the same way that TCH does get benefit from DTX. The interference of the SACCH for a first of two paired remote stations is continuously present at the receiver of the second paired remote station.

On the other hand, if the paired MUROS users employ the mapping method in Shifted-SACCH mode shown as FIG. **20**, SACCH information for the first paired remote station is transmitted simultaneously with the TCH frame of the second paired remote station and vice versa. If DTX is enabled or active, SACCH information could be transmitted in GMSK modulation with full power when the paired user's speech is inactive, thereby making the SACCH data link more immune to degradation of the link. Therefore in this case, the SACCH performance is improved.

Relative performance of the Associated Control Channel (ACCH) compared against the traffic channel (TCH) was evaluated by graphing ACCH link level performance. The ACCH comprises the fast associated control channel (FACCH) and the slow associated control channel (SACCH).

FIG. **21** is an illustration of a DTX performance analysis of the C/I used by SACCH for 1% FER versus the C/I used for TCH for 1% FER. The figure represents the relative performance of a legacy DARP receiver and a MUROS (or VAMOS) receiver, including comparison with and without DTX. Curve **211** represents legacy DARP TCH. Curve **212** represents legacy DARP SACCH. Curve **213** represents MUROS (VAMOS) TCH with no DTX. Curve **214** represents MUROS (VAMOS) SACCH with no DTX. Curve **215** represents MUROS (VAMOS) TCH with no DTX. Curve **216** represents MUROS (VAMOS) shifted SACCH with DTX. As FIG. **21** shows, the identification letters a and b denote the difference in the value of C/I used to achieve a 1% FER (i) for the SACCH and TCH of the legacy DARP receiver and (ii) for the SACCH and TCH of the VAMOS receiver, respectively. For example identification, a, on the graph illustrates that the legacy DARP SACCH (curve **212**) uses a higher C/I ratio to achieve a 1% FER than the legacy DARP TCH (curve **211**). Likewise identification, b, on the graph illustrates that the MUROS SACCH with no DTX on (curve **214**) uses a higher C/I ratio to achieve a 1% FER than the MUROS TCH with no DTX on (curve **213**).

The values c and d denote the performance improvement of the TCH (curve **215**) and the SACCH (curve **216**) when DTX is on for a MUROS/VAMOS receiver. For example, identification d on the graph illustrates that the MUROS SACCH with no DTX (curve **214**) requires a higher C/I ratio to achieve a 1% FER than the Shifted-SACCH with DTX (curve **216**).

Likewise, identification c of the graph illustrates that the MUROS TCH with no DTX (s curve **213**) requires a higher C/I ratio to achieve a 1% FER than the MUROS TCH with DTX on (curve **215**). For simplicity, 1% FER point is used for both TCH and SACCH. Thus, the performance degradation of SACCH when VAMOS is introduced could be obtained as follows:

$$SACCH_{degrad1}=b-a,\text{when DTX is off}$$

$$SACCH_{degrad2}=b+c-a,\text{legacy MUROS mode when DTX is on}$$

$$SACCH_{degrad3}=b-d+c-a,\text{shifted-SACCH mode when DTX is on.}$$

From above it can be seen that the performance degradation will be greater when DTX is on (i.e. active). That is, the ratio of the C/I used to achieve a 1% FER for the SACCH, to the C/I used for the TCH, i.e. the degradation associated with the SACCH, is greater for legacy MUROS remote terminals **123**-**127** than for legacy DARP remote terminals **123**-**127**, i.e., $SACCH_{degrad2}>SACCH_{degrad1}$.

A legacy MUROS remote terminal does not use the time-shifted SACCH or shifted-SACCH mode. A non-legacy MUROS remote station uses the time-shifted SACCH i.e. operates in shifted-SACCH mode.

If the shifted-SACCH method is employed for MUROS users, the situation will be improved. That is, the performance degradation will be less because the SACCH signal transmitted by a first base station for a first remote station will not interfere with the SACCH signal transmitted by the first base station for a second remote station. Equally the SACCH signal transmitted by the first base station for the second remote station will not interfere with the SACCH signal transmitted by the first base station for the first remote station.

The SACCH signals do not interfere because they are time-shifted relative to each other i.e. they are substantially non-cotemporaneous. The relative performance of SACCH against TCH for a shifted-SACCH mode could even be smaller than that of legacy DARP receiver.

Consequently, SACCH degrad3 may be smaller than zero.

The difference between the SACCH and the TCH C/I performance could be reduced by using a shifted SACCH. The link level performance of SACCH would match better with the TCH. That is, the C/I used by the SACCH to achieve a 1% FER would be much closer to the C/I used by the TCH if the SACCH for the first remote station is staggered or time-shifted relative to the SACCH for the second remote station. This would increase voice capacity for situations in which the SACCH communication channel is subject to performance degradation while the TCH communication channel has adequate performance.

Simulation Assumptions:

The simulation assumptions are shown in Table 7 below.

TABLE 7

Simulation assumptions of link performance

Parameter	Value
Propagation Environment	Typical Urban (TU)
Terminal speed	3 km/h
Frequency band	900 MHz
Frequency hopping	Ideal
Interference/noise	MTS-1, MTS-2
Antenna diversity	No
DARP receiver	VAR receiver
Tx pulse shape	legacy linearized GMSK pulse shape
Trainning sequence	Existing sequence and new sequence proposed by NSN
Channel type	TCH AHS4.75, SACCH
Interference modulation type	GMSK, QPSK
SCPIR	0, −3 dB
DTX	On/Off

Simulation Results:

FIG. **22A** is a graph of the TCH and SACCH performance without DTX. Curve **221** represents performance for SACCH and curve **222** represents performance for TCH DTX was modeled by a Markov state model with activity of 0.6 with average activity period of 1 s.

FIG. **22B** is a graph of the TCH and SACCH performance with and without DTX. Curve **223** represents performance for TCH with DTX, curve **224** represents performance for TCH with no DTX, curve **225** represents performance for SACCH with no DTX and curve **226** represents performance for SACCH with DTX.

Simulation results of SACCH relative performance with and without DTX are tabulated in Table 8 and Table 9 below.

TABLE 8

SACCH relative performance compared to TCH for DTX, MTS1				
	Legacy DARP	OSC_GMSKIntf	OSC_GMSKIntf_legacyMUROS_DT	OSC_GMSKIntf_ShiftedSACCH_DT
TCH/AHS4.75	0 dB	0 dB	−0.5 dB	−0.5 dB
SACCH	1.8 Db	2.6 dB	2.6 dB	1.2 dB

TABLE 9

SACCH relative performance compared to TCH for DTX, MTS2			
	legacy DARP	MUROS_−3dB_QPSKIntf	MUROS_−3dB_QPSKIntf_legacyMUROS_DTX
TCH/AHS4.75	0 dB	0 dB	−0.6 dB
SACCH	1.8 dB	2.9 dB	2.9 dB
			MUROS_−3dB_QPSKIntf_ShiftedSACCH_DTX
		TCH/AHS4.75	−0.6 dB
		SACCH	1.3 dB

From Table 8 above, it can be seen that the relative performance of SACCH versus the traffic channel for a half-rate channel coder 4.75 (TCH/AHS4.75) is degraded in legacy MUROS mode (4th column) when DTX is on compared with the degradation found in a legacy DARP receiver (2nd column) The relative value in mobile telephone system 1 (MTS1) is from 2.6 dB to 3.1 dB. The degradation of SACCH versus TCH/AHS4.75 in MUROS mode compared to a legacy DARP receiver is from 0.8 dB to 1.3 dB. If the shifted-SACCH method is used, the relative performance of SACCH is better than a legacy DARP receiver.

The same situation also exists in a MTS2 example as illustrated in Table 9. The degradation is from 1.1 dB to 1.7 dB when DTX is on. If a shifted-SACCH method was used, the loss of SACCH relative performance to a TCH would be decreased from 1.7 dB to 0.1 dB in a mobile telephone system 2 (MTS2) scenario.

It is noted that the simulation results here are not the maximum degradation value. Some aspects such as SCPIR interference type may influence the degradation value. Then the link level performance degradation of SACCH for VAMOS may not be neglected.

In one example of SACCH performance, absolute performance is checked against a spec point of a DARP receiver. The value is shown in Table 10. Next, another criteria of associated control channel (ACCH) performance evaluation was measured. Relative performance of the ACCH compared against the traffic channel was simulated at the link level.

TABLE 10

SACCH absolute performance degradation		
	MTS-1	MTS-2
SACCH absolute performance compared with DARP spec point	6 dB	4 db

In another example, the relative performance of SACCH versus TCH in DTX mode is further considered. Simulation results are given in Tables 11 and 12. Table 12 illustrates the advantage of using shifted-SACCH.

TABLE 11

Relative value between SACCH and TCH by introducing VAMOS		
	MTS-1	MTS-2
the relative value between SACCH and TCH of the legacy DARP receiver (non-VAMOS)	1.8 dB	1.8 dB
the relative value between SACCH and TCH in VAMOS mode	2.6 dB	2.9 dB
the relative value between SACCH and TCH in VAMOS mode when DTX is on	3.1 dB	3.5 dB
the relative value degradation by introducing VAMOS	1.3 dB	1.7 dB

TABLE 12

performance improvement after using Shifted SACCH scheme		
	MTS-1	MTS-2
the relative value between SACCH and TCH in VAMOS when DTX is on	3.1 dB	3.5 dB
SACCH performance improvement using Shifted SACCH scheme when DTX is on	1.4 dB	1.6 dB
the relative value between SACCH and TCH using Shifted SACCH scheme	1.7 dB	1.9 dB

From Table 11 it can be seen that the relative value between SACCH and TCH is degraded about 1.7 dB when VAMOS is introduced. If a shifted SACCH method was used, the performance of SACCH would be improved and the relative value between the C/I used by the SACCH and the TCH for 1% FER would be maintained at legacy non-VAMOS level. The results can be seen in the last row of Table 12.

In addition, all the results above are based on a fixed SCPIR all through the 26-multiframe. For further SACCH performance improvement, the SCPIR may be adjusted at the SACCH frame allocation. With the same transmission power level, the SACCH sub channel may have higher power ratio while the TCH sub channel has a little bit lower power ratio. The relative performance of SACCH and TCH may be further improved with an appropriate SCPIR value.

Compatibility Consideration

Impacts on the Remote Station **123-127**

The presented concept operation uses at least one VAMOS mobile station supporting Shifted SACCH mapping in the paired users. The VAMOS mobile station can operate using the new mapping method within a 26-multiframe. The support of Shifted SACCH mapping is signaled to the network. There is minimal impact on the measurement results of the remote terminal **123-127** and minimal impact on the hardware implementation.

Impacts on the BS **110**, **111**, **114**

Both the transmitter and receiver are used to implement the new mapping method in VAMOS mode. When the BS **110**, **111**, **114** triggers the downlink power control, a delay of several frames for SACCH information between the two subchannels may be taken into account. The downlink power level decided by the BS **110**, **111**, **114** may be kept the same as that in a legacy mapping method because of the un-impacted measurement results. For the uplink power control, the BS **110**, **111**, **114** handles the measurements for two subchannels separately, and makes a decision on uplink power levels for the two subchannels based on their measurement results. The difference between the shifted SACCH and the legacy SACCH methods is that the power control commands may not be sent to the two users at the same frame. The receiving time in the remote terminal **123-127** side has a slight interval between these power control commands. Since the power control period is typically 1.5 sec, such a small interval may be insignificant.

There is minimal traffic channel performance degradation when only shifting a SACCH frame position. Regarding the TCH frames position changes after a SACCH frame is shifted, the maximum speech block interval is just one frame more than in the legacy mapping case. This kind of tolerance is acceptable by the BS **110**, **111**, **114**.

Using a shifted SACCH method impacts the mapping scheme of the users in VAMOS mode. Thus, there is insignificant impact on the Abis interface and A interface than that caused by using the VAMOS mode.

In the above examples, the impact of DTX on the SACCH relative performance was analyzed and some simulation results were presented. From the analyses and the simulation results, it may be seen that the link level performance of SACCH may benefit from using a shifted-SACCH method especially in a DTX mode.

From the above analyses, shifted SACCH is a simple solution to achieve the purpose of improving the relative performance of SACCH compared against TCH at legacy non-VAMOS level. Furthermore, shifting SACCH frame allocation allows more flexibility to balance the performance between SACCH and TCH by simply tuning the SCPIR.

In another example, using repeated SACCH is an alternative solution to improve the performance of SACCH.

The skilled person would understand that method steps described in the description and illustrated in the accompanying drawings can be interchanged without departing from the scope of the invention.

The skilled person would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits and symbols that may be referenced in the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

The skilled person would further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the examples disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled persons may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

The various illustrative logical blocks, modules, and circuits described in connection with the examples disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The steps of a method or algorithm described in connection with the examples disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An example storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In another example, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. Alternatively, the processor and the storage medium may reside as discrete components in a user terminal.

The description of the disclosed examples is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these examples will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other examples without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the examples shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method for determining capabilities of a remote terminal by a base station, the method comprising:

maintaining an active voice call with the remote terminal;

sending a single discovery burst to the remote terminal during a first time interval;

receiving a first response from the remote terminal;

sending multiple discovery bursts to the remote terminal during a second time interval following the first time interval;

receiving a second response from the remote terminal;

sending a progressively increasing number of discovery bursts to the remote terminal during subsequent time intervals until a threshold is reached; and

determining whether the remote terminal is capable of multi-user on one slot operation based on the first response and the second response.

2. The method of claim **1**, wherein the single discovery burst is sent in place of a slow associated control channel frame.

3. The method of claim **1**, wherein a known interference pattern is superimposed on the single discovery burst.

4. The method of claim **1**, wherein the single discovery burst comprises a first signal and a second signal on a single channel, wherein the first signal comprises traffic data for the remote terminal, wherein the traffic data comprises a first predefined data sequence, wherein the second signal comprises a co-channel signal, and wherein the co-channel signal comprises a second predefined data sequence.

5. The method of claim **1**, wherein the first response indicates a bit error probability measured by the remote terminal.

6. The method of claim **1**, wherein the first response indicates an RxQual parameter for one slow associated control channel period.

7. The method of claim **1**, wherein the first response indicates an RxLev parameter indicating average signal strength received.

8. The method of claim **1**, wherein no discovery burst is sent during a third time interval immediately following the first time interval and preceding the second time interval.

9. The method of claim **1**, further comprising selecting the remote terminal for co-channel operation if the remote terminal is capable of multi-user on one slot operation.

10. An apparatus for determining capabilities of a remote terminal by a base station, comprising:

a processor;

memory in electronic communication with the processor; and

instructions stored in the memory, the instructions being executable by the processor to:

maintain an active voice call with the remote terminal;

send a single discovery burst to the remote terminal during a first time interval;

receive a first response from the remote terminal;

send multiple discovery bursts to the remote terminal during a second time interval following the first time interval;

receive a second response from the remote terminal;

send a progressively increasing number of discovery bursts to the remote terminal during subsequent time intervals until a threshold is reached; and

determine whether the remote terminal is capable of multi-user on one slot operation based on the first response and the second response.

11. The apparatus of claim **10**, wherein the single discovery burst is sent in place of a slow associated control channel frame.

12. The apparatus of claim **10**, wherein a known interference pattern is superimposed on the single discovery burst.

13. The apparatus of claim **10**, wherein the single discovery burst comprises a first signal and a second signal on a single channel, wherein the first signal comprises traffic data for the remote terminal, wherein the traffic data comprises a first predefined data sequence, wherein the second signal comprises a co-channel signal, and wherein the co-channel signal comprises a second predefined data sequence.

14. The apparatus of claim **10**, wherein the first response indicates a bit error probability measured by the remote terminal.

15. The apparatus of claim **10**, wherein the first response indicates an RxQual parameter for one slow associated control channel period.

16. The apparatus of claim **10**, wherein the first response indicates an RxLev parameter indicating average signal strength received.

17. The apparatus of claim **10**, wherein no discovery burst is sent during a third time interval immediately following the first time interval and preceding the second time interval.

18. A non-transitory computer-readable medium having instructions thereon, the instructions comprising:

code for causing a base station to maintain an active voice call with a remote terminal;

code for causing the base station to send a single discovery burst to the remote terminal during a first time interval;

code for causing the base station to receive a first response from the remote terminal;

code for causing the base station to send multiple discovery bursts to the remote terminal during a second time interval following the first time interval;

code for causing the base station to receive a second response from the remote terminal;

code for causing the base station to send a progressively increasing number of discovery bursts to the remote terminal during subsequent time intervals until a threshold is reached; and

code for causing the base station to determine whether the remote terminal is capable of multi-user on one slot operation based on the first response and the second response.

19. The non-transitory computer-readable medium of claim **18**, wherein the single discovery burst is sent in place of a slow associated control channel frame.

20. The non-transitory computer-readable medium of claim **18**, wherein a known interference pattern is superimposed on the single discovery burst.

21. The non-transitory computer-readable medium of claim **18**, wherein the single discovery burst comprises a first signal and a second signal on a single channel, wherein the first signal comprises traffic data for the remote terminal, wherein the traffic data comprises a first predefined data sequence, wherein the second signal comprises a co-channel signal, and wherein the co-channel signal comprises a second predefined data sequence.

22. A method for providing capabilities of a remote terminal to a base station, the method comprising:

maintaining an active voice call with the base station;

receiving a single discovery burst from the base station during a first time interval;

sending a first response to the base station;

receiving multiple discovery bursts from the base station during a second time interval following the first time interval;

sending a second response to the base station, wherein the first response and the second response indicate whether the remote terminal is capable of multi-user on one slot operation; and

receiving a progressively increasing number of discovery bursts during subsequent time intervals until a threshold is reached.

23. The method of claim **22**, wherein the single discovery burst is received in place of a slow associated control channel frame.

24. The method of claim 22, wherein a known interference pattern is superimposed on the single discovery burst.

25. The method of claim 22, wherein the single discovery burst comprises a first signal and a second signal on a single channel, wherein the first signal comprises traffic data for the remote terminal, wherein the traffic data comprises a first predefined data sequence, wherein the second signal comprises a co-channel signal, and wherein the co-channel signal comprises a second predefined data sequence.

26. An apparatus for providing capabilities of a remote terminal to a base station, comprising:

a processor;

memory in electronic communication with the processor; and

instructions stored in the memory, the instructions being executable by the processor to:

maintain an active voice call with the base station;

receive a single discovery burst from the base station during a first time interval;

send a first response to the base station;

receive multiple discovery bursts from the base station during a second time interval following the first time interval;

send a second response to the base station, wherein the first response and second response indicate whether the remote terminal is capable of multi-user on one slot operation; and

receive a progressively increasing number of discovery bursts during subsequent time intervals until a threshold is reached.

27. The apparatus of claim 26, wherein the single discovery burst is received in place of a slow associated control channel frame.

28. The apparatus of claim 26, wherein a known interference pattern is superimposed on the single discovery burst.

29. The apparatus of claim 26, wherein the single discovery burst comprises a first signal and a second signal on a single channel, wherein the first signal comprises traffic data for the remote terminal, wherein the traffic data comprises a first predefined data sequence, wherein the second signal comprises a co-channel signal, and wherein the co-channel signal comprises a second predefined data sequence.

30. The apparatus of claim 26, wherein the first response indicates a bit error probability measured by the remote terminal.

31. The apparatus of claim 26, wherein the first response indicates an RxQual parameter for one slow associated control channel period.

32. The apparatus of claim 26, wherein the first response indicates an RxLev parameter indicating average signal strength received.

33. The apparatus of claim 26, wherein the remote terminal is selected for co-channel operation if the remote terminal is capable of multi-user on one slot operation.

34. An apparatus for determining capabilities of a remote terminal by a base station, comprising:

means for maintaining an active voice call with the base station;

means for receiving a single discovery burst from the base station during a first time interval;

means for sending a first response to the base station;

means for receiving multiple discovery bursts from the base station during a second time interval following the first time interval;

means for sending a second response to the base station, wherein the first response and the second response indicate whether the remote terminal is capable of multi-user on one slot operation; and

means for receiving a progressively increasing number of discovery bursts during subsequent time intervals until a threshold is reached.

35. The apparatus of claim 34, wherein the single discovery burst is received in place of a slow associated control channel frame.

36. The apparatus of claim 34, wherein a known interference pattern is superimposed on the single discovery burst.

37. The apparatus of claim 34, wherein the single discovery burst comprises a first signal and a second signal on a single channel, wherein the first signal comprises traffic data for the remote terminal, wherein the traffic data comprises a first predefined data sequence, wherein the second signal comprises a co-channel signal, and wherein the co-channel signal comprises a second predefined data sequence.

38. A non-transitory computer-readable medium having instructions thereon, the instructions comprising:

code for causing a remote terminal to maintain an active voice call with a base station;

code for causing the remote terminal to receive a single discovery burst from the base station during a first time interval;

code for causing the remote terminal to send a first response to the base station;

code for causing the remote terminal to receive multiple discovery bursts from the base station during a second time interval following the first time interval;

code for causing the remote terminal to send a second response to the base station, wherein the first response and the second response indicate whether the remote terminal is capable of multi-user on one slot operation; and

code for causing the remote terminal to receive a progressively increasing number of discovery bursts during subsequent time intervals until a threshold is reached.

39. An apparatus for determining capabilities of a remote terminal by a base station, comprising:

means for maintaining an active voice call with the remote terminal;

means for sending a single discovery burst to the remote terminal during a first time interval;

means for receiving a first response from the remote terminal;

means for sending multiple discovery bursts to the remote terminal during a second time interval following the first time interval;

means for receiving a second response from the remote terminal;

means for sending a progressively increasing number of discovery bursts to the remote terminal during subsequent time intervals until a threshold is reached; and

means for determining whether the remote terminal is capable of multi-user on one slot operation based on the first response and the second response.

* * * * *